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OF THE

WESTERN SOCIETY

OF

ENGINEERS

PAPERS, DISCUSSIONS, ABSTRACTS, PROCEEDINGS

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VOL. II. FEBRUARY, 1897. No. 1

I.

STREET RAILWAY CONSTRUCTION.

BY EWD. BARRINGTON, MEM. W. S. E.

Read November 18, 1896.

MR. PRESIDENT AND GENTLEMEN:

Being selected to occupy the time originally allotted to a paper on "Cableways," by our esteemed fellow-member, Mr. Frank B. Knight, an authority on such matters, it is somewhat embarrassing to attempt to hold your attention with such a threadbare subject as that selected for my discourse this evening, and more especially as able authorities have already covered the ground. However, I crave your kind forbearance, should my efforts not prove at least instructive.

Twenty-five years ago my first interest in this line of work was aroused, while my father was engaged in the introduction of our system of street locomotion in Dublin, Ireland. Since then the evolution in this character of construction has been surprising. I will not, however, weary you with a recapitulation of ancient history, but confine myself to existing methods, connected more or less intimately with electric street railway construction, touching lightly upon the power station and matters associated with the generating plant. This covers a good deal of ground, but it is impossible to embrace all details in a single lecture.

The "bête noir" of a trackman is a rough and unstable rolling surface, and his dream an absolutely "permanent way" as near as practicable. This is, likewise, a matter of considerable vexation and perplexity to street railway managers, municipal authorities and engineers, who have devoted much thought to it. Still the results are anything but satisfactory.

The advent of the electric motor has caused a revolution in construction methods—rolling loads having increased from 5,000 to over 60,000 pounds within a few years—rough joints, rattling and noise of cars had to be abolished; the weight of the motor,

resting on the axles, produced a hammer blow at the joints; the high speed of the cars and their great weight; and millions have been expended to secure something approaching what would be considered an "ideal track," exceeding in stiffness and strength even the steam railway permanent way. The rails were gradually increased in weight and height, and altered in section from the flat-strap to the girder form; this affected the depth of foundations and increased the extent of necessary excavations, and placed the ties further underground and more difficult to get at, and some roads even placed chairs on the ties to support the rail, thus increasing difficulties of maintenance. But, although this resulted in a heavy and costly construction, it is not by any means as durable as was hoped for, with the introduction of the girder rail and its long and heavy joints.

One cause of much tribulation is, that the joints are permitted to remain too long without attention, and the removal of the paving delayed until it is absolutely necessary to make repairs.

The possibility of continuous rails will eliminate this trouble to a great extent. Electric welded or the cast welded rails are practically continuous, the cast welding being the less expensive. There are now over 200 miles of these continuous rails in use, and they appear to give satisfaction.

Large ties, close spaced, in or on concrete foundations, will give good support to the track. It is costly, but necessary. It is generally believed that the rail should have an elastic support, yet we find on cable roads the rail resting directly on the cast-iron yokes with good effect, and no harm to rails or cars.

Metal ties, in place of the large timber ties, thoroughly bedded in concrete, would be an improvement on the ordinary work.

Perhaps a rail with a broad base, laid directly on the concrete, thus altogether eliminating the ties, would be sufficiently solid. This plan has been adopted in Minneapolis and Europe with girder rails. There is one thing certain, the elimination of wooden ties will effect an enormous saving in repairs.

Location.—Suburban traffic has grown recently to such an extent that proper location is now a matter of much importance. Localities must be considered, and the most direct, easiest and cheapest line. The future must be considered, possibilities of increasing traffic, and the route must present attractive features.

Subsequent to deciding the location, the line is staked out, and grades fixed and set out by instruments, and not by rule of thumb or the eye, as is generally done. Grades should be uniform, sudden changes being avoided where possible. Careful estimates of the quantity of excavation and embankment are necessary, and the most advantageous manner to provide for them; then locate all curves, switches and turnouts; providing easiest transition curves, and an elevation of the outer rail from one to two inches above the inner one, where conditions will permit, but particularly on sharp curves and when curves are situated on a grade.

Locate switches, crossovers, and turnouts, so as to provide for bunching cars for large gatherings, and to insure the operation of cars during fires, parades and other blockades when, from any cause, the terminus of the road cannot be reached. Never place the switch points against the traffic; and preferably, on the up grade, thus enabling the cars to cross to the opposite track by gravity.

Road-bed.—Where necessary, the road-bed should be well drained with tiles, laid directly under the track, and the trenches filled with coarse material, gravel or broken stone; this drain should be laid three feet below the track grade. The width excavated for the foundation of the track should be two feet greater than the length of the ties. The depth depends upon the height of the rail, thickness of ties, depth of the concrete, etc., usually eight inches below bottom of tie. It is difficult to fix any arbitrary depth, as so much depends upon the solidity of the ground, and it should remain for the engineer to decide such points. This is a matter which requires careful watching; in some places a depth of four inches might be sufficient to allow for the concrete, while in others twelve inches would be required. Soft places, if not provided for, will soon make themselves felt. If the road is adjacent to a wagon road, it should be at least a foot higher, well drained and thoroughly protected from water. Give the sub-grade a thorough rolling.

Should ditches be necessary, study the adjacent water-shed, and be sure to make them sufficiently large. Along a single track they should be well outside the trolley poles, and if the line is double track, place them at least seven feet outside the ends of the ties. Never carry water under the track, if avoidable; and where imperative, use iron or terra cotta pipe, or stone culverts. Never use wooden boxes, even temporarily.

The Twin City Rapid Transit Company, Minneapolis, has adopted a near approach to permanent track construction. The rail is five inches by five inches, "T" section, weighing eighty pounds per yard, but with a depth of seven inches it is thought much better results would be obtained. The rails are laid and brought to grade and line while supported on temporary wooden ties. As the work progresses, after the spaces between the cross ties and under the rails are concreted, the ties are removed and all holes are filled with concrete. Granite blocks are set along the inside of track, and left from ten to fourteen days for the cement to thoroughly set, after which an asphalt surface is laid in the usual manner. Sufficient time must be given for the concrete to harden before the track is put in service. Under each rail, running the full length of track, is what might be termed a concrete beam, fifteen inches wide and eight inches deep, on which the rail rests. It will be observed that no timber enters into the construction, and nothing to rot, and the only part to wear is the rail.

The specifications of the Chicago City Railway call for:

"Paving.—The roadbed is now filled to within eight inches of the

top of the rails with medium fine limestone, thoroughly tamped. Upon this are placed 1½-inch hemlock boards, running lengthwise of the track." This is rather an unusual construction, and not to be commended.

Should broken stone ballast be used for foundation, there should not be less than six inches under the ties, well tamped. The broken stone should be rolled with a ten-ton roller until eight inches of stone is compressed to about six inches.

Upon the broken stone foundation are laid the ties. If stone pavement is not used, but simply broken stone or macadam, it is filled in between the tracks, as soon as the bolts and splices are tightened, nut locks on, and bonding completed, and well tamped and rolled with light roller, say five-ton, so as not to spread the rails.

Concrete.—The depth should be determined by the engineer in charge, but will vary from four to twelve inches according to the exigencies of the case, or solidity of the foundations. The concrete width is usually one foot outside the ties at each side, or nine feet in width for a seven-foot tie. The constituent parts of the concrete are one part of cement, two parts of sand—sharp—and four or five parts of broken stone or gravel, small enough to pass through a two-inch ring. Mix the sand and cement dry, and turn over four times before using water. Wet the stone before adding it to the sand and cement and mix thoroughly on a board platform with tight joints. After spreading concrete, ram it thoroughly, until water appears on the top, keeping it uniform and smooth. Spread one inch of coarse sand or gravel over the concrete for tie bed. The space between the ties should be filled with concrete, broken stone, gravel or sand, as the engineer decides, thoroughly tamped or rolled and brought to an even surface, ready for the paving, which should be impervious to water.

In the suburbs the track should be well ballasted, using broken stone, gravel, screenings, or cinders, with sufficient loam to make it pack when thoroughly tamped.

Bridges—Where bridges of short span are found necessary, deck girders or "I" beams should be used, the girders resting on solidly built stone supports, on a good foundation. Be sure to provide an ample waterway, with plenty of headroom, so that floating timber cannot injure the sub-structure or super-structure.

On electric lines great care should be taken to have the track smooth on bridges and viaducts. This is not usually the case. Frequently we meet the old tram rails, of horse car days, still on these places, and even where girder or "T" rails are laid, the joints are permitted to get low, because it is a little trouble to remove the planking in order to bring them to their proper level.

Teams are prohibited from moving faster than a walk over these bridges, etc., yet we see the electric cars, weighing ten tons or more, wildly careering across them at six to ten miles an hour.

These low joints are seldom considered by engineers in calculating safe loads and making rules governing travel on bridges.

Danger of derailment is increased, and only recently has resulted in the collapse of two bridges.

Guard-rails are very essential, as well as safety-gates at drawbridges. In outlying districts, of course, timber structures can be used on pile or trestle foundations.

Ties.—The ties should be of white oak, rock oak or chestnut, well seasoned, and, if practicable, creosoted or treated with some wood preserver, free from decayed knots or other unsound parts, hewn on two sides with straight faces, of an even thickness, sawed off square at each end, and stripped of the bark. No ties should be hewn from one-half or one-quarter logs, or sawed from large timbers.

The dimensions of the ties should be seven feet long by eight inches wide by six inches deep or thick, spaced equally and laid fifteen to the thirty foot rail. Some roads prefer an eight-foot tie.

Very few engineers claim to have solved the problem of the most economical track construction by adopting the metal tie.

Metal ties require for their proper foundation a thorough bedding in concrete, and as a concrete foundation is necessary in any good track, the selection of metal ties bespeaks good judgment in deep-rail construction; but, curious to say, most American engineers claim that concrete is not necessary in first-class track construction, and if this opinion be correct, then there can be few cases where the metal ties would be satisfactory and economical.

Creosoted ties last twelve years, while untreated ties seldom last over six years. Dividing up the cost per annum, it is about the same for each, viz., 9.5 cents per annum; but with the creosoted tie, there is the expense of renewals saved once every twelve years, quite an item of importance to railway managers. Insure 120 inches of bearing surface to each 30-foot rail.

Rails.—The rails usually run from 70 to 95 pounds to the lineal yard; width of base, 5¾ inches, and of head 2½ inches, and preferably 60 feet long, to avoid joints and present a better riding surface. Full-grooved girder rails are used exclusively in Washington, Richmond and Buffalo, and abroad also; it gives a center bearing, pavements can be laid close to it and flush with the top; there is no obstruction to vehicles, and it affords no tramway for the wheels of heavy wagons to run on and interfere constantly with the street car service. There has been much contention relative to the best kind of rail head. There seems to be no uniformity in practice. As a general thing the "T" rail section has been adopted, although many lines still adhere to the tram-top girder rail. Joints should be staggered, 15 feet apart. Splices should be six, eight or twelve holed, according to weight of rail, with full complement of bolts and nut locks. The rail should be mounted on a tie-plate, and many roads use tie-rods to keep the track in gauge, but the best

method is to use a combination tie-plate and rail-brace. Where the rails are spiked to the ties, the inside spikes should be opposite each other, and the outside spikes opposite, for obvious reasons. In fastening the rail to the ties, if the tie-plates are not used, care should be taken to give the rail a good bearing across the entire face of the tie. As the average hewn ties will not permit this, they must be adzed off before the rail is laid. If this be not done, the rail will work under the pressure of the cars. The most satisfactory way to fasten the rail to the ties is by means of tie-plates. Plates with a raised lug to prevent the rails spreading, and with claws to hold them to the tie, answer several purposes. They keep the track in gauge, which spikes will not do, they lengthen the life of the cross ties, and hold the track in surface better. Rail chairs, which bolt or spike to the tie, and upon which the rail rests, are practically useless where traffic is heavy, as they will work and break and are a constant source of annoyance. The preservation of the gauge is very important, and tie-plates will do this better than any other method. If put on every other tie they will hold the rail, but, if used on every tie, they will make a more solid and lasting piece of work. Joints should always be supported.

Where permitted "T" rails are used, as being most economical. Where not permitted, the girder rail, from five to nine inches in height, is generally adopted. There are a great variety of patterns or sections, and the weight runs from 107 pounds per yard down to 16 pounds per yard, which is about the smallest sized steel rail at present in use. The West Chicago street railway rail is a grooved rail, nine inches high, with fish-plates, weighing together thirty pounds to the foot, and one-inch bolts.

Steel rails, properly supported by cross-ties, will sustain as a maximum a weight per wheel of 2,240 pounds for each ten pounds weight per yard of rail.

Many street railway men contend that the grooved rail requires four times as much tractive power as the side bearing head, owing to the tendency to hold dirt, snow and ice, and therefore is not as easily kept open to traffic. My experience has been that these rails are better finished, ride smoother, and are without trouble kept clean, free from snow and ice in winter, and no difficulty is encountered in trying to keep the road open for traffic.

The width of the base of the ordinary girder, which is designed to be spiked directly to the ties, is not so difficult to determine as the height ,and the best practice makes the base and the height the same.

It is now generally conceded that a harder quality of steel in the rails than is usually furnished is essential. None of the high-carbon rails on the New York Central Railway near Spuyten Duyvil have broken after six years of unusually heavy traffic, though the makers saw fit to warn the railway company that they would not be responsible for any damage resulting from the use of what they considered as unfit material.

"Steel inspectors" say that high-carbon rails will give from 40 to 60 per cent longer life than rails of ordinary Bessemer steel. To-day these rails cost no more than ordinary steel rails.

The composition of the rails should be as follows:

Carbon, from .53 to .63 per cent.

Phosphorus, not to exceed .095 per cent.

Sulphur, not to exceed .07 per cent.

Manganese, .080 to .100 per cent.

Silicon, .10 to .12 per cent.

The fact that there is a longer life to rails of hard steel will appeal to every railroad man as an economy which cannot be sacrificed.

In laying tracks, be sure the joints are laid without open spaces between the ends of rails, no matter what the temperature is, and when in position bolt the splices up, driving them home with a hammer. Be sure the joints are perfectly tight.

In driving spikes, try gage on every tie. Use spikes 5½x9-16 inches, four on every tie. When track is spiked and bolted thoroughly it is ready for surfacing, tamping, aligning and bonding.

The prevailing practice of using such heavy rails is most costly and to our mind unnecessary. Were the joints given more attention the rails might be reduced to 66 pounds per yard, instead of 80-95 pounds. In a 100-pound rail there is but 30 pounds of wearing surface, of which not more than 12 or 18 pounds can be used before the rail will have to be thrown out; therefore there will be 88 to 82 pounds unused.

In Syracuse rails are being now laid 60 feet long, 9 inches high and of the half-groove section. They are connected by a ribbed or corrugated 12-bolt, 36-inch joint.

Tie-plates.—It has been found a fact, from steam-road practice, that a rail having its base directly against the wooden face of the tie, "chews" the wood away, and that the interposition of even so thin a piece of metal as one-quarter inch in thickness, when made of sufficiently large area, prevents this. It has also been found to be a fact, that when the spikes are driven through holes provided in these plates, that the spikes hold the rail securely to the tie for a much longer time than where no plate is used. Smooth tracks, to true gage, are absolutely essential, more especially on electric roads. Tie-rods. will not do, but the brace will, hence the advent of the "brace tie-plate." Some engineers advocate the use of a "clip" struck up or riveted on the tie-plate to hold the inside flange of the rail down to its place. This has been proved to be impracticable. More experience is required to form a decided opinion. The "Johnson Company" makes a single brace plate and tongue, and the "Mark Railway Equipment Company" has a double brace-plate. Both are preferable to tie-rods, which are, generally speaking, an abomination in the sight of the repair men. Where brace-plates are used, spikers must use the gage rod at every tie, but with the tie-rods, they are more careless and will probably spike every other tie, using the gage.

Chairs.—The less amount of chairs used the better, and their only necessity is to give the required height for the paving. An increased height in the web of rail will secure the same purpose, and much more effectively. Should chairs be mandatory, however, care should be exercised in selecting such as will insure the greatest possible bearing on the tie, and such only as will not spring under heavy loads. A chair with a narrow base is apt to cut into the cross tie, and in time work loose or cause the rail to cant.

All intermediate chairs should be provided with a brace, extending well up under the outer head of rail, which is the best safeguard against the rail turning over.

Joints.—Splices should be 26 to 36 inches long, punched for six, eight or twelve bolts, three-quarter inch to one inch in diameter, and are most generally used, but they demand much attention, even when nut-locks are used.

The corrugated plate of the Johnson Company is admired by many. It should cover at least two ties, and preferably three.

The Milwaukee Electric Railway Company has thoroughly tested the Falk cast-welded rail joints, and the tests show rather phenomenal results. It certainly seems to indicate that bonding is not only absolutely unnecessary, but the joint actually proves a better conductor than the rail itself, as the resistance of the joint is less than the same length of the rail. The general manager, Mr. C. D. Wyman, states that "by the results of these tests he feels sufficiently assured of its utility to continue the use of the cast-welded joint, without bonding, upon his system, believing ample margin is shown for any prospective deterioration likely to occur in the life of the joint underground."

It makes an absolutely continuous rail of the track, and without the sign of a joint on the thread of the rail. It has withstood a temperature variation of from 100 degrees above zero to 24 degrees below zero.

The "Wheeler" joint seems to have many good points. It is a malleable iron wedge joint, with re-inforced ribs, especially adapted to use on electric railways. There are no nuts to work loose, no bolts to stretch, and no letting down of rails. They save time in track laying, and once applied, it is there to stay without further attention, saving expense of frequent removals and replacing of pavement. It prevents pounding of rail ends and racking of rolling stock, it has large bearing surface on rail and gives good support to the joint; it can be adapted to any style of rail, and can be used either as a suspended single or double tie joint.

The Standard Boston & Philadelphia type of joints is good for deep girder rails of heavy weight.

Break joints at about one-third the length of the rails and better results will follow than by breaking in the center.*

* NOTE: Relative to breaking joints one-third of rail length in place of in the center as is customary; if any one curious to know the effect, will make a sketch and study it for a moment, I fancy their curiosity will be satisfied. This practice has given much satisfaction to those who have experimented with it. Of course, where the rails are cast-welded, or the joints are strongly and firmly spliced, or the foundation is practically perfect or nearly so, it makes little difference where you break joints.—B.

Bonds.—Nearly every road has its own favorite bond, including channel pins with single, double and triple lacings, Chicago bonds, plastic bonds, riveted bonds, Atkinson bonds, etc. These are all good and it is difficult to choose between them. Bond wires using soldered rivets have been universally condemned. In some cases return feeders, aggregating in length less than five miles, have been used, but the rails themselves are depended upon for the return in the generality of cases. Underground supplementary wires are sometimes employed. Earth returns are used to a limited extent, and only where the points to be connected with the power station run near salt water. Here the earth plate is made by employing old dash iron, from which the paint has been cleaned, and which is buried below low tide mark. The connection to the rail is made by riveting and soldering a conductor connected to the rail. Sometimes old cast frogs and mates are employed instead of dash iron. The station earth plate is made in the same way.

The method of testing the bonds is with a low reading voltmeter, the connections being made by filing the rails on each side of the joint until a bright surface is obtained. As the current flowing through the joint is usually unknown, however, this method of testing is anything but satisfactory.

Tie-Rods.—Use tie-rods with high rails, or where the rails are supported on chairs or stringers, four or five feet apart. Heavy flat steel bars, not less than one and a quarter inches wide, and from one-fourth to one-half inches thick, with three-fourths of an inch round, threaded ends. Two nuts are used on each end to facilitate adjustment, and jam-nuts are employed on the outer ends for additional security.

Paving.—In cities the paving may be Belgian block, brick, concrete or asphalt, and in the suburbs ordinary earth is used, if ballast of broken stone, gravel, screenings or cinders is too expensive.

Much trouble is occasioned by the loosening of the pavement along the rails and over the ties. It should be laid close and compact, with the interstices filled with paving pitch or grout, so as to insure its being impervious. Where macadam, concrete or asphalt is used, there should be next the rail a "toothing" of block paving, of stone or brick, to prevent disturbance of the pavement by the rail vibration.

Fine cement is used on each side of the rail web to allow the paving to fit against the lip of the rail. The usual depth of Belgian blocks is six inches, and they rest on a bed of sand one inch deep. There should be no projections to prevent the pavement from fitting close to the rail.

Concrete is much preferred abroad for foundation to broken stone; in fact, the latter is never allowed to be used.

With brick paving, the concrete should be brought to within one inch of the bottom of the bricks, then one inch of sand, spread very evenly, and lastly the bricks, laid very true, no brick the least bit higher than the adjoining ones.

Where "T" rails are used, special bricks must be furnished of different lengths to lay next to the rails on the inside of the track, so as not to be in the way of the wheel flange, and forming a groove along the rail. Track drains are placed at intervals of 400 feet and at points of break of grade. At Richmond, Va., the ties are bedded in concrete, while at Cortlandt, N. Y., the ties are laid underneath the concrete bed, and the rails rest on chairs, placed upon the ties. This is not a good method of construction.

In Washington, Buffalo, New York and Chicago, asphalt pavement has been laid to a large extent; its chief objection is, the tendency to wear ruts along the rail, and the spring of the rail—should there be any—loosens the pavement. The cost is high, and generally speaking it is not favorably looked upon. To overcome the first objection, in some localities where this paving is adopted, a double row of granite blocks is laid, adjoining the rail, which also provides for the vibration of the rail, and renders it more accessible to get at the foundation of the roadbed for repairs. Brick or wood could be used for the same purpose.

In suburban districts, Telford paving is sometimes used, owing to its cheapness. It is laid by placing stone, known as rip-rap, as close together as the same can be laid, and filling the interstices with broken stone, which is laid for a depth of three inches, over the rip-rap, and thoroughly rolled, and covered with a thin coating of sand or gravel.

Wood paving is also extensively used, owing to its cheapness, but is not durable on account of its rapid wear from heavy traffic; and decay, caused by atmospheric changes, and not keeping it damp. Further, owing to the expansion of wood, when absorbing moisture, the blocks bulge upward in places, and in instances have caused the closing of slots in cable roads, and the breaking of various portions of the running gear of both cable and electric cars.

It can safely be said wood paving has seen its best day and is rapidly becoming obsolete.

With girder rail construction, some roads fill in the web of the rail with moist clay just before paving, in order to prevent the paving blocks from working loose, caused by the sand surrounding them filling up this space and leaving the blocks unprotected and tending to cause adjoining blocks adjacent to the track to settle unevenly. Other roads provide an iron frame at each joint, so that repairs can be made without disturbing the paving; but with existing girder rail joint construction, ties well tamped and bedded in concrete, and bolts securely fastened, this is unnecessary.

Curves.—In laying out the curves, the regular curvature is not carried through the entire length of curve. If it is, the change from the tangent or straight line to the curve is so abrupt that the wheels will strike the point of curve instead of traveling easily on to it. To avoid this, flatten the end, use a spiral, or ease off the curve.

Proper elevation should be given, depending on rapidity of car

movement; but, if possible, it should be avoided, as it is very difficult to keep road in shape, unless it is very solid and well ballasted.

When ordering special work connected with curves, give angle, radius, distance between tracks, and full information as to weight, height, and drilling of rails, not forgetting holes for bonds.

If possible furnish sketch, showing building and curb lines with clearance required.

There are the following methods of guarding curves: High "T," or Shanghai rails, are guarded with flat guard; the "T" rail guard is elevated three-quarters inch and held to main rail by bolts and fillers spaced two feet apart. Wrought iron plates are used for spiking. The flat guard is sometimes used with lighter sections of girder rail, and by those roads preferring a renewable guard on curves; the grooved rail guard is formed by raising the inner portion of the rail from one-quarter to three-eighths inch above the tread. For barn curves, a "T" rail of about 40 pounds per yard is generally used.

Radius of curves should not be less than 35 feet for cars with a five-foot wheel base, and double-track curves leaving a double track should not be struck from the same center. For the inside curve give the longest practicable radius, and for the outer curve a radius that will not lessen distance between cars. Widen gauge one-half inch and raise outside rail if practicable.

Frogs, Switches, Crossings, Etc.—Frogs should be solid, and the switches also. Those made up of several pieces bolted together invariably get loose and rattle. The manganese steel special work gives the best results. The wide tread used on the wheels of steam railroads when worn to a double flange makes the wear and tear on crossings very severe. In order to overcome this the reinforcing rails are put on. These rails carry the extra flanges and the train passes over as smoothly as if wheels were true. The usual openings are 1¾ inches on steam roads and from 1 to 1¼ inches on street railways By getting the flangeway on street railway as narrow as possible, it lessens the jar on steam track and increases the life of the crossing. The guard rail is sometimes omitted on street railway tracks of crossings, thus considerably decreasing the cost. Always furnish a sketch when ordering crossing; give gauge, designate which track is street and which is steam railway, and give angle of crossing. State height, weight and drilling of rails used on both tracks, not forgetting bond wire holes, if any. Make tracing of ends of rails, showing sections. Should tracks be on curves, give direction of curves and radius of same. Cable street railway crossings are more complicated and somewhat troublesome

For turnouts and crossovers, the leads should be such as to permit of economical use of rails, generally two 30-foot rails connecting tongue, mate and frog, making it necessary to order fixtures only, the connecting rails being cut in on the ground.

Turnouts should be diamond shape and not less than 250 feet in

length, and the track should be a perfect tangent to the lead. Drop or blind switches are not suitable for electric roads.

The interlocking of street railway crossings of steam railways at grade is a matter which should receive the consideration of all interested officials. The signals should stand normally at "stop" for the electric cars, and should not be lowered by the towerman until he is advised that the block is clear.

Sometimes it is necessary to provide a system of interlocking that will prevent all possible chance of accident. On the steam track are two semaphores, one on each side of the crossing, at a distance to be governed by circumstances. On the street railway track are two derails, likewise situated. Both the semaphores and derails are connected by pipe line to the interlocking switch stand, and are controlled by it. The semaphores are normally at safety, giving the steam road right of way. The derails are normally open, making it impossible for a car to go over crossing until they are thrown. There are several ingenious derailing switches on the market.

In ordering crossovers, specify that the straight track rail be continuous, as in most work of this kind the reverse is the rule. The aim is to favor the track most used.

Maintenance.—If the track is well and properly laid, the maintenance will be a small item, but necessary repairs should not be neglected. Cheap work is poor policy, as repairs will be frequent and a constant drain on the resources of the company, which will soon exceed what a sound construction would have cost at first. The gauge must be maintained exact. Inequalities will cause the cars to ride badly. Line and surface must also be kept in good shape. A rough road will lose passengers and disgrace the management. The roadbed should present a clean and ship-shape appearance, and the ditches be lined up and free from weeds and dirt. In the fall give the track a thorough overhauling in preparation for winter, especially if laid on soft ground. If well ballasted, the frost will not easily affect it, but if not cold weather will cause it to heave, then the only resort is to use shims in the worst places, and wait until the frost escapes from the ground. In the spring put on extra trackmen and get track in shape quickly, replacing ties where necessary and fixing up thoroughly. Three good men will take care of eight miles of well-laid and ballasted track. Educate your trackmen and it will well repay you.

Where block paving is used, all protruding blocks should be taken out and replaced where they will be out of the way of snowplows, should they happen to be called out.

On horse lines which are unpaved it is a good idea in the fall to fill the horse path with crushed stone or cinders. It will prove timely economy.

Overhead Construction.—The poles are placed 125 feet apart when at the side and 110 feet apart when in the center. A heart pine or cedar pole will, if properly selected and kept painted, last in some climates twenty years. Steel span poles for forty-feet spans

weigh 700 pounds, made in two parts, the lower six-inch extra heavy standard steel pipe, and upper section five-inch, swaged at the joint for a distance of 18 inches, 28 feet long, 18 feet for lower and ten feet for upper section, provided with a cast-iron and wood pole top for the attachment of span wires. Wood filling at bottom, to prevent pole from sinking, six feet in the ground, raked ten inches from perpendicular. Wood poles should be of long leaf yellow pine, dressed and chamfered, 30 feet long, sawed square, 11x11 inches at the base, and 7x7 inches at the point, free from sap, rot or knots, and corners evenly chamfered.

The standard trolley wire is No. 0, B. & S. gauge, hard drawn copper, with conductivity of 98 per cent, or usual standard in tables. Span wires should be of No. 4 "B. W. G." silicon bronze wire. Splicing ears for joints have been the rule, and strain ears are located every 1,000 feet, on each side of curves or overhead crossings. Guard wires are of No. 4 "B. W. G." galvanized steel. Soldered ears are used throughout. The general electric, bronze overhead parts are almost exclusively used. Feeder cables must be weather proof insulated, the insulation being hard, smooth and pliable, and not affected by changes in temperature. The sizes of feeders are No. 0000, B. & S., 300,000 C. M., and 500,000 C. M. Cast iron brackets, with wrought iron pins, support the feeder cables. Line, pole, stays or insulators should not detract from the beauty of the streets. There are myriads of different insulators, but recently uniformity in design is the rule. The section insulator and the colophite insulator are both highly commended. An automatic trolley cut-out has lately been put on the market, and is quite a convenience. Creosoted pine poles are good insulators and will last five years if properly treated. Lightning arresters should be placed every 1,000 feet. The members will pardon no further allusion, in detail, to overhead parts, such as turnbuckles, crossings, switches, bonding pins, ears, as my time will not permit, although it is a most important and interesting part of the work.

Standards.—There should be a more thorough standardization of electrical railway apparatus. Definite rules should be fixed. Motors, generators, switches, circuit breakers, etc., etc., should be precisely defined. This is only just to manufacturers and users. This would abolish the infinite different methods of rating electrical apparatus. Small and new roads suffer principally from this lack of standards, owing to not having skilled engineers. For example, notice the difference existing in defining the capacity of generators and motors. The varying features necessitated by the construction of motors for various characters of service offer great opportunities for mystery, and even the most efficient engineers are occasionally imposed upon by misused terms.

For motors and generators, there should be prescribed rules as to the character and method of their insulation.

Rules should likewise be formulated in connection with installation, whether it is done by car builders, contractors, manufactur-

ing companies or by the company itself. Manufacturers will be only too happy to conform to these requirements.

The steam roads of the country have done much towards fixing standards and rendering interchangeable materials and parts. This gives to the railways, aside from all other advantages, a cheapened cost to the manufacturers and consequently to the road, due to the reduction of the number of different parts and sizes. These and many other points will suggest themselves which apply even more forcibly to street railways than to steam railroads.

It seems almost to be impossible to select some of what might be close to standard dimensions. The following are some carefully selected: Axle diameter, 3½ inches; car axle journal diameter, 3 in.; axle wheel seat diameter, 3⅛ in.; length of car axle journal, 8½ in.; diameter of car wheel, 33 in.; diameter of trolley wheel, 4½ in.; width of trolley wheel, 1½ in.; depth of groove in trolley wheel when new, 1½ in.; size of key way for axle gear, ⅜ in.x6 inches; distance between hubs of wheels measured along the axle, 48 inches.

It is very essential that the groove and depth of trolley wheel be the same, as it is impossible to put up an overhead construction that will carry a variety of trolley wheels.

The standardization of parts should be so directed as not to interfere with the progress of invention.

Power Plant.—Select carefully the site, centrally located to the system, accessible to coal supplies and water for condensing purposes, etc. Build for the future and save your money is the best policy. Determine very carefully the required capacity of your engines, boilers and generators, which will govern the size of your buildings, etc. As prime movers, we have water, steam, gas or oil. The two latter are receiving much thought now. The direct-coupled plant costs a little more than the direct-belted with independent engines, but enormously less than any plant based on large engines, with the attendant mass of counter shafting, clutch pulleys, belts, belt-tighteners, etc. Add to this the real estate and building item, and the chances are in favor of reducing the original investment one-half in an ordinary city plant. The relation of this fact to dividends is apparent. In constructing a plant, heavy losses accrue from misplaced material, which, being lost sight of, necessitates replacing. Keep precise account of all material required, ordered, received and used. Most of the plants here are steam. Small stations use high-speed dynamos and larger stations, the low-speed direct connected machines. Simple engines changed to compound and even triple expansion with condensers, where it is possible. Although the tendency is in the direction of continuous current stations, perhaps direct currents are preferable, as they admit the employment of storage batteries, which equalize the load on the station, quite a desideratum, nowadays.

On large roads, power costs about 10 per cent of the operating expenses. The building should be fire proof; the walls of brick, the roof of slate, tile or iron, and the floors of concrete or

iron. Insurance is thus obviated. Carefully consider style, size and arrangement of machinery, so that no part of the building will interfere with the proper repairs, renewals and inspection of the apparatus. Contracted areas of buildings frequently hamper operations and the introduction of desirable forms of apparatus.

The engine room and boiler room are divided by a brick wall and under different roofs; both should be brick buildings covered with an iron truss roof; the boiler room should be set on the grade of the street, and the engine room 10 or 12 feet above this grade, the space below the engine room being utilized for the piping and condensers; the engines and boilers should be set at right angles to the wall between them, with the engines next to the boiler room, so that the piping is made as short as possible, and the condensation lessened; the switch board and feeder board should be set on the opposite side of the room from the boiler room, so that the length of the dynamo cables is equalized as much as possible. The power house should be compact, to save real estate and buildings and to minimize the number of employes and the superintendence. Large units are used for the sake of economy and to save the number of working parts.

Provide 30 to 40 h. p. per car, for roads operating many cars. The cost of steam plants complete, including smoke stack and building is, for high speed and non-condensing engines, from $45 to $60 per h. p. For compound engines, $60 to $75 per h. p., and for electrical equipment from $35 to $45 per h. p. Eight square feet of heating surface, evaporating 30 pounds of water per hour, is the usual limit of h. p. for sectional or water tube boilers, and 15 square feet the unit for tubular boilers.

Boiler Room.—Water-tube boilers possess some marked advantages over the fire-tube. They are non-explosive, may be operated at a higher pressure and are more suitable for use with compound engines; they have a large heating surface and quickly respond to calls for power; they occupy less floor space and are better designed. They are more costly, more joints to be looked after, cleaning is more difficult, especially where curved tubes are used. Their efficiency is usually higher than fire-tube, but they now make a fire-tube boiler, with a shell of large diameter and extra length, containing a large number of flues, which approaches the water-tube very closely in efficiency.

Babcock & Wilcox boilers, in batteries of two each, having a capacity of 500 h. p. on thirty pounds of water, are largely used. Mechanical stokers are the vogue, and deservedly so. They are universally used in the eastern states, but, in most western cities, they have proved unsuccessful. At the end of the boiler room is the pump room, containing Worthington feed-water pumps, Metropolitan injectors, oil injectors, and necessary piping, etc. Every well regulated boiler room has "Green economizers" and "Goubert separators" in use, the latter connected with both the high-pressure cylinder and with a reducing valve leading to the low-pressure

cylinder, so that the latter can be cut out, and worked independent of the former. Round steel chimney stacks have superseded the obsolete brick structure, the latter being relegated to a condition of innocuous desuetude.

Many companies are abandoning their chimneys for producing draft, and use an induced draft produced by fans placed in the flue or short stack, and the stack is just high enough to clear the roof. There is absolute control in governing the fires, which is an especial advantage where the loads are suddenly and rapidly changing. The boiler room is supplied with blowers in place of stacks, and a slow fire is kept constantly under many boilers. When a call for power is expected, the blower is started and steam is quickly raised in sufficient quantity to supply any demand.

The feedwater is metered, filtered and clean before it reaches the suction tank. The piping system is important, and is shunted, so that the pumps can be cut in direct with the boilers, if necessary.

Opinion is divided regarding the general plan of piping. Some favor a single header with leaders to the engines. Others approve of a complete duplicate system, so that no serious stoppage could be caused by a failure in any single part of the system. The latter increases greatly the cost. A compromise system has been adopted by some companies, in which all pipes are duplicated, each side, however, having only one-half the capacity required, necessitating the use of both sides all the time. In case of accident to one side, the other half of the system may be used, at a disadvantage, of course, by increasing the steam pressure. The best plan, however, seems to be to use a single header divided at convenient intervals by valves, according to the size of the plant and the number of the units employed, and to use only the best valves, material and workmanship. The simple system gives the least amount of trouble. The pipe coverings giving the best results are the magnesia plastic and sectional coverings, and the asbestos fire felt covering.

Injectors are ready to take the place of the pumps for boiler supply should occasion arise. The piping and the cylinders of the engines and pumps are steam jacketed. The live steam to each engine is first lead to a second separator directly under the engine and used mainly as a reservoir and pressure equalizer for it. Mechanical handling practically wipes out the cost of handling coal and ashes, and mechanical stoking successfully and smokelessly burns all kinds of fuel at less than half cost of hand firing.

A recording steam gauge is found useful in checking up the firemen.

Engine Room.—The engine room should have two traveling cranes of 20-ton capacity each, and a smaller one at the entrance. The equipment depends entirely on the power in demand. Owing to the varying load, the duties imposed upon the engines are greater than usually come on such machines. The Watts-Campbell cross compound engine, 26x48x48″, will develop at the most economical

point of cut off, from 900 horse power to 1,000 horse power, and can operate safely for any length of time up to 1,600 horse power. They are operated at a speed of 80 revolutions per minute.

The speeds which are most common are 75 revolutions per minute for the 1,500 K-W. dynamo, 80 to 120 revolutions per minute for the 800 K-W. dynamo, and speeds running from this to 150 revolutions per minute for the smaller sizes. Most of these engines possess the same characteristics, outside the question of valve gear; the heavy bed-plate, the solidly constructed fly-wheel, now being made of steel plate, the wide cross-head, the large connecting rod and the mammoth main bearings. The upright engine requires less space than the horizontal, but the latter is the cheaper, the simpler, the easier to inspect and the easier to repair. The upright engine has less wear on the cylinder, and a more direct strain upon the foundations. Compound engines are usually installed now. Where condensers are not used, the cost of fuel must be very high for the gain in compounding to pay for the extra investment.

I would like to say a few words regarding the Westinghouse, Corliss and other engines, but time will not permit.

The generators, switchboard and lubricating system should all receive very careful consideration.

The first cost of the direct coupled generator is about 35 per cent more than the belted generator in the 500 K-W. size, which is the largest standard size in which the belted generator is made; but when the expense of the belt, belt-tightening device and the floor space is taken into account the direct connected generator will be found the cheaper. In large sizes and in connection with large engines it has a much higher efficiency than the belted unit, requires a smaller space, aids supervision by bringing the working parts of the engine and generator close together, reduces danger, is almost noiseless in operation, and it may be installed in a larger unit than the belt driven generator, which is limited in size by the width of the belt and pulley which may be employed. The large, slow-speed, multipoler, direct-driven generator has become the most prominent feature of the modern power house. The switchboard has become standardized to the extent that it consists of a panel for each generator, each panel containing the usual automatic circuit breaker, ammeter, field rheostat, field switch and main switch. As now erected they usually contain a recording Watt meter and an ammeter which shows the total output of the power house.

Most of the generator and feeder boards are supplied with devices for preventing damage to the station machinery by lightning, but a very simple and effective arrangement is to connect a large water rheostat between the positive bus-bar and a good ground. This is either left in circuit continuously with a small current running through it, or is cut into circuit on the approach of a storm.

Boosters, or high voltage dynamos, are used by many companies operating long lines, which are constantly in circuit. It is automatic in its action and raises the voltage with every increase

in the load. Other companies operate a high voltage dynamo for use on sections which are subject to excessive loads. The feeder boards in these cases are equipped with an extra bus-bar, so that any section may be thrown on the high voltage machine.

An air pressure system is beginning to be used, by which the carbon dust may be blown out of the armature windings, and the armature is kept thoroughly clean, and the danger of short circuits occurring on account of collection of carbon dust between its conductors is lessened. This city will soon possess three engines, 30x60x60", 2,300 horse power each, at 75 revolutions per minute.

Cost of operation.—The lowest results are about ¾ cents per K-W. hour; others run as high as 1¼ cents per K-W. hour. These figures include the cost of coal, water, supplies, repairs and all labor, but do not include anything for taxes, insurance, interest or depreciation. The cost of operating depends largely on the price of coal and upon the relation of the average load to the total capacity of the power house, the higher this ratio the less being the cost of operation.

Rolling Stock.—The types are almost infinite. The twenty-foot single truck car is advised for ordinary city work, and the twenty-five-foot double truck car for interurban lines. Many roads do not use trailers. Snow plows and sweepers must always be on hand; White's plow and McGuire's sweeper are approved. Each car should carry a telephone and cut-out boxes placed every 1,000 feet. Provide a low step on open cars. The Walker Company "new trolley" is much admired. It swings around easily and never comes off the wire. No switches are required, and the switch-plates are not cut to pieces. You know the present trolley is controlled by one patent. The 6 A. Peckham truck is a good standard for 20-foot single truck box cars, and the 6 D. Peckham for the 20-foot open cars. For double trucks, the Brill No. 23 truck is advised, although many stick to the maximum traction trucks. Some regard the Robinson radial trucks with favor. Recently the Brill Company have brought out their No. 27 truck, which presents many features of importance and interest.

The four-wheel truck is an uncomfortable carriage and a track destroyer, and should only be used where cars are run at comparatively slow speed, and with moderate length of car bodies. At high rates of speed the damage to track becomes so great that its use should be precluded. By all means adopt the double truck car in such cases, with swivel or pivoted trucks; it is easy on curves, reduces weight on each wheel, is less destructive to the track, and there is no oscillation either way. There are, however, many objections to the pivotal truck. If all the weight is used for adhesion it is twice as expensive in use as the four-wheel truck. If two motors are used it only has 50 per cent of the propelling power.

The motor should be mounted on the truck, so as to secure the greatest flexibility. The weight should be cushioned on the axle and truck by springs. This method of suspension tends to increase

the life of the gears and pinions remarkably. Those in general use are the Westinghouse No. 3, G. E. 800, G. E. 1,000, G. E. 1,200. Of these the G. E. 1,000 is preferred for general use. The Walker Company also turns out an exceptionally good motor. Motors should receive a thorough inspection daily. The controller is an important element. Its casing must be protected from moisture, and the cover, instead of being hinged, should be arranged so that it is entirely removed and can be set to one side out of the way when it is desired to get at the internal portion of the controller. The wheels are subjected to severe service. Flat wheels occasion much trouble, and they show a tendency to wear with a sharp flange on one side and a double flange on the other. Manganese steel wheels do not flatten, but they wear one to two inches in diameter in covering 20,000 miles. Chilled iron wheels weigh 360 pounds each and average 3,000 miles in service per month. Pay the wheel makers more and secure a better wheel thus. The most reliable braking apparatus must be secured, regardless of cost. The air brake has been well developed and affords a high degree of protection. It is simple in construction, easily operated and inexpensive in the matter of maintenance, and where they are used there should be no flat wheels.

A momentum friction brake has been in use here for the past six months, which has proved so successful that many more will be placed on other cars in the near future.

Many managers think "fenders" are a menace, and prefer clear headed motormen. Still they should be attached to all cars, and likewise "grab handles" around the front of the cars, so that people could save themselves, or try to do so. Electric heaters are very satisfactory, but it is claimed that they cost three times as much as stoves in operation. To offset this, stoves cost about $1.50 at the beginning of the season to put in shape for use.

Special cars are much in demand for different purposes. We have the combination, box, flat, mail, express, vegetable, funeral, private and other types, the utilization of which presents one of the most interesting features connected with their operation. Trolley parties are very common. The prevalent practice is to light the cars by electricity, but Pintsch gas lighting is preferable, as it is softer and more satisfactory. What do the managers of steam roads think of these innovations? The car equipment should receive thorough daily inspection. In fact, there should be a trip inspection, a daily inspection and a monthly inspection. The dust and dirt should be removed from around the armatures and fields as far as possible with compressed air or a hand bellows. Wipe commutator, remove brushes and see that they are in good order and the copper peeled back on them, so they will not wear into the copper coating during the next day's run, thus avoiding the musical squeak which this would cause.

Use of Salt and Sand on Tracks.—The use of salt on the rails at certain times and during certain conditions of weather is absolutely necessary in order to clear the rails of a film of ice that will other-

wise form on them. Without the use of salt it would be very unsafe to operate cars on a hilly system during winter, and no road can afford to dispense with its use, more especially in the operation of electric cars.

In like manner, sand is a necessity on the rails in order to give the wheel a "proper grip" on the track. In the city of St. Louis the quantity of salt dumped on the tracks is in excess of 3,000 tons in the course of one winter. Local authorities or health board do not object to the use of salt.

The use of sand is also absolutely necessary, and its use should not be interfered with.

Sand Boxes.—Sand boxes should be a part of every car. Their operation is very simple, through a pedal, bell crank and connecting rod. The valves and gears are of malleable iron.

Steep Grade Traction.—On steep grades electricity has proved itself superior to other forms of traction, remarkable results having been attained. Heavy motors and series of parallel controllers are needed. The toothed armature cores, instead of smooth cores, and the protected field spools, reduce the item of motor repairs, and a large share of the power formerly wasted at starting is saved by the new controllers. In San Francisco two 25 horse power motors, on each single truck car, are used on the very steep grades. Single truck cars are preferred to double truck cars, as they have more adhesion in proportion to the weight carried. The amount of power required to propel a car up a grade is independent of the speed. If the speed is slow, the force required is less, but the time during which it is exerted is longer. If the speed is rapid, the force is greater and the time is less, so that the result is the same in either case.

Employes.—Make a careful selection of your employes. Place them under a bond. Have competent instructors, who will teach the duties and regulations of the company. Motormen should return reports each evening. If trouble is reported, an inspection should be at once made, and repairs carried out forthwith. The organization of clubs, where lectures can be given frequently, illustrated by stereopticon views of underground trolley, cable machinery, etc., etc., are found advantageous; still, the individual instruction plan is preferable, if possible. Every employe should be thoroughly examined and made to graduate from the general school of instruction.

Accidents.—Accidents are mostly due to carelessness of motormen. Drawbridges should be carefully protected by safety gates and other precautions. Do not run too close to your theoretical consumption of power. Single track lines should be "blocked." Insure ample means to provide safety and certainty of operation on steep grades. Prohibit overloading. Accidents caused by defective apparatus, poorly conditioned motormen, gross carelessness, the "fool killer" or fate cannot be averted. Reversing the car to prevent an accident is very liable to pull the circuit breaker out at a most critical moment.

Competition.—What is the effect on steam railway receipts of the

competition of trolley roads? It is strong in some localities, still is ignored by the steam roads pretty much, although it has had the effect of reducing rates and improving service in some cases, whereas in others the service has been reduced and retrenchment in other directions carried out. Information on this subject is very desirable.

Revenue from Surplus Power.—Why should not electric traction companies sell their surplus power to manufacturers as a means to reduce loss from idle machinery and to produce an additional source of revenue? The objections of the insurance companies in some districts, or board of fire underwriters, seems to be embraced in the one feature of ground return, which is well grounded, too, but why not make the same objection to the arc light circuits, with their 3,000 to 5,000 volts difference of potentiality, and their invariable grounded circuits, coming into any building? With protected wiring and reliable insulators, both systems could be made absolutely safe.

Electricity from Coke.—It is announced that the problem of direct conversion of coal into electricity has been solved by Dr. Jacques. The subject has been carefully investigated by eminent scientists and engineers, and a company formed with ample capital, who are convinced that the practical development of a great system is in sight. This means a reduction of our bill for power of $100,000,000 annually. It would save annually to the people of this country more than two and a half times the amount collected from our everlasting tariff fees. It would save five or six times as much as all the silver that would be offered for coinage, should a free coinage measure be enacted.

Car Barn.—The car barn is an exceedingly important part of the equipment for electric lines, and its construction and arrangement should have careful consideration. The building should be roomy and sufficiently high between joints to allow for wiring, so that cars can be shifted by means of the current. In addition to the tracks, offices, wash room, elevators and transfer cars of ordinary barns, there should be provided a sufficient number of pits, over which the cars can run to facilitate repairs to the motors. These pits should be provided with steam pipes for warming, and with portable electric lights.

The machine shop should be a part of the car barn, or located near it, and should be equipped with a suitable number of iron working tools. The power for these tools may be supplied by a small steam engine or by a stationary electric motor. Facilities should be provided for winding and making all necessary repairs to armatures.

The tool equipment of the machine shop for the repairs on from twenty to sixty cars should consist of a lathe, a shaper, milling machine, drill press and emery wheel.

The repair shop is the first and most important consideration in the building and operating of an electric line, and should be built and equipped before any part of the line has been put in operation;

and, as stated above, the power to operate it may be derived from a stationary motor, deriving its current from the line, or by a steam engine.

Purchase the best apparatus, provide means to take care of and repair it, and secure competent help (skilled mechanics), and supply them with requisite tools and machinery to perform their work, in a thorough workmanlike manner and economically, and place a master mechanic in charge. This is an economical policy. He can make better material than he can buy. He is familiar with the requirements and conditions of the business. Those who operate the road know exactly what they need, and are better judges of the strength and durability of their apparatus than those who never have seen it.

Further, much material now on the market is not by any means standard. I make no reflections on the manufacturers, but this is the fact, simply because the manufacturers do not understand the requirements of the business. Some may be unscrupulous enough to put goods on the market just for what is in them for awhile, regardless of their stability. There is a saving of 25 to 50 per cent by manufacturing your own parts. Investigate the matter.

The wrecking wagon should be provided with ladders, jacks and all necessary tools for making trolley repairs and for replacing or removing a derailed car.

A tower wagon should be provided as part of the equipment for line repairs and overhead work. A full complement of tools for a gang of five men, including foreman, for overhead construction and repairs, would comprise the following. Not all would be absolutely required, but it would be found convenient to have them, and the list will form a basis for the organization of the different gangs. Besides the tower wagon, there should be a light wagon and one reel wagon, two 22-foot ladders and one tool box, two sets each of large and small tackle, one dozen hauling clamps, two hauling clamp wrenches, four straps and vises, six pair six-inch gas pliers, six eight-inch side pliers, one bolt cutter, two twelve-inch monkey wrenches, six twelve-inch flat bastard files, two fourteen-inch round files, two fire pots, two railway soldering irons, two blacksmith hammers, one ratchet brace and three bits, two cold chisels, one hand saw, one twelve and one sixteen-inch screw driver, one wood mallet, one 100-foot tape line, one hack saw and blades, one acid jug with brushes, one fourteen-inch Stillson wrench, two 100-foot hand lines, one small soldering ladle, one hatchet, six lanterns, one bushel charcoal.

For night inspection one man will be required for every ten or fifteen cars, depending on the type of motor; with gearless motors the inspector's work is much reduced. An inspector should be provided with three monkey wrenches, six to fourteen inches in size, one pair of six-inch pliers, hammer, cold chisel, soldering furnace and iron, and one ten-pound sledge hammer.

See that the connecting cables are in good condition and that the insulation is not chafed or broken. Provide sufficient cars to

allow weekly inspections without reducing number of cars in service.

All car houses, power stations, and other offices should be connected by an independent system of telephone wires, so that a general oversight of the operation of the line is had by the superintendent and other officials.

There should be sufficient emergency stations, equipped in the usual way, and when the traffic is exceptionally heavy, emergency teams and gangs should be placed at different points along the line, where they can be easily summoned by telephone. The emergency force can be largely recruited from the repair shop force and expert motormen and others, whose places are for the time taken by extras. Another important feature of the successful maintenance of the service is the employment of a considerable number of "traffic inspectors." These are expert motormen, who have served in the repair shop, and besides looking out for the spacing of cars, etc., are fully competent to assist in making temporary repairs or helping the management in case of accident, such as the breaking of the overhead line, etc. The inspectors rank above the conductors and motormen, and immediately assume control, and summon tower wagons by telephone if necessary. Each inspector has a certain territory assigned to him daily, which, however, is not always the same, as on days of heavy traffic the territory of each will be made smaller and a greater number of men will be put in service.

Accounts should be kept according to the system recommended by the American Street Railway Association.

From the last census returns I cull the following interesting data relative to the cost of construction, cost of operating, etc.:

	Cable.	Electric.	Horse.
Cost of road and equipment per mile of line, street length.......$	350,324	$ 46,700	$ 71,400
Passengers carried per mile per year	1,355,965	222,648	596,563
Passengers carried per car mile...	4.38	3.46	4.95
Operating expenses per car mile, cents	14.12	13.21	18.16
Interest charges per car mile, at assumed rate of 6 per cent, cents.	6.79	4.35	3.55
Sum of operating expenses and interest per car mile, cents..........	20.91	17.56	21.71
Operating expenses per passenger carried, cents	3.22	3.82	3.67
Interest charges per passenger, at assumed rate of 6 per cent, cents	1.55	1.26	0.72
Sum of operating expense and interest, per passenger carried, cents	4.77	5.08	4.39

On electric roads, the ratio of operating expenses to receipts is approximately 60 per cent.

With horse cars the operating expenses are about 80 per cent of the receipts.

Please bear in mind these figures are averages. Some are much lower, and others considerably higher. For instance, in Chicago the ratio is about 40 per cent, while in Newcastle and Gosforth, England, it is 90.5 per cent.

The statistics of the operation of electric railways are those of an operation less settled and uniform than that of either cable or horse railways.

The expense per car mile of operating cable roads vary from 9.39 to 21.91 cents.

The operating expenses of electric railways run from 8.34 to 36.04 cents per car mile, and the variation for horse railways is from 9.10 to 27.02 cents per car mile.

Many of the facts presented here are, gentlemen, a record of actual experience, and as such are believed to have considerable value, notwithstanding the unsatisfactory character of some of the conditions attending that experience.

Permit me to thank you for your kind attention, and accept my apologies for the dryness and uninteresting developments of the subject, for much of which I am indebted to the authorities who furnished me the data from which the pith is selected.

II.

NATURAL DISTORTION OF ROCK IN PLACE AS SHOWN ON THE CHICAGO DRAINAGE CANAL.

By Chas. L. Harrison, Mem. W. S. E.

Read December 23, 1896.

When the rock which composes a part of the crust of the earth is exposed, evidences are revealed of disturbances, of a greater or less degree, that have taken place since the formation of this rock.

The opening of the quarries in the Desplaines valley from Sag

Fig. 1. Showing fissure 3 inches wide in rock. Section 11, Chicago Drainage Canal.

Bridge to Joliet, and the excavation of the Chicago Drainage Canal, have afforded unusual opportunities for studying the effect of the forces that have been and are now at work distorting and changing the rock from its original position.

Niagara limestone, which is the outcropping rock in the Desplaines valley, is of a sedimentary formation with a stratification that is nearly horizontal. It is checked with parallel vertical seams or fissures running northwest and southeast, and similar checks at nearly right angles to these. The result being to divide the whole mass of rock into nearly rectangular blocks which vary in length from a few feet to perhaps a hundred feet in extreme cases. These vertical seams are usually close, but many of them are from one-half inch to one foot in width and filled with clay.

Fig. 1 shows one of these fissures three inches wide on Sec. 11 of the drainage canal. It extends from the surface of the

FIG. 2. Showing fissure 1 inch wide and fault in rock. Section 11, Chicago Drainage Canal.

FIG. 3. Showing two fissures fifty feet apart and fault in rock between them. Section 12, Chicago Drainage Canal.

rock to the bottom of the channel, a depth of 33 feet, and continues down indefinitely. When the excavation of the channel was first made this fissure was filled with clay, which has since been washed out by rains.

A fissure one inch wide is shown in Fig. 2. By observing the stratification of the rock a fault of about six inches will be seen at the fissure.

Fig. 3 shows two fissures about fifty feet apart, the whole mass of rock between them having dropped down about six inches as shown in the stratification. Near the Illinois Stone Co.'s quarry above Lemont there is a fault of over three feet, and near Joliet there is one of about thirty feet.

It certainly requires force of great magnitude to produce these changes in the position of the rock.

Throughout the Desplaines Valley there are numerous instances of the distortion of the upper strata of the rock which are different from those shown in Figs. 1, 2 and 3. They usually occur adjacent to and on each side of the fissures, extending several feet in depth and frequently several hundred feet in length. Figs. 4 and 5 show two of these near Lemont. There are many others in the same vicinity of the same general character, but these are taken as fairly good representatives. At this point there have been no excavations made. The rock is at the surface of the ground, being covered with black dirt varying in thickness from nothing

FIG. 4. Distortion of upper strata of the rock.

FIG. 5. Distortion of upper strata of the rock.

to one foot. These views then show the appearance of the distorted rock at the surface of the ground and do not give any definite information as to the depth they extend below the surface. Many of them are cut by the I. & M. canal and are shown to extend down to and below the water surface. The drainage canal passes through a number of these risings in the rock. The channeled walls being clean cut and smooth enable one to readily trace the depth to which this distortion of the ledges extends. Fig. 6 shows a general view of a characteristic one. To the left of the middle of this view will be seen a fissure extending from the top to the bottom of the channeled wall, a depth of about thirty-three feet. The top ledge on each side of the fissure is upturned about one foot and the next lower ledge not quite so much, and so on down to a depth of about ten feet, where there is no distortion of the rock. A great number of similar risings exist along the line of the canal, but this one is sufficient to show their character.

The changes of the position of the rock shown in the above views were probably made centuries ago. A study of the developments in connection with the excavation of the drainage canal leads to the belief that the forces which produced them are still at work producing similar changes. The channel was excavated through the rock in three lifts of from ten to twelve feet each. In many instances where these risings show at the surface of the ground, as in Fig. 6, they would, in a short time after the first lift

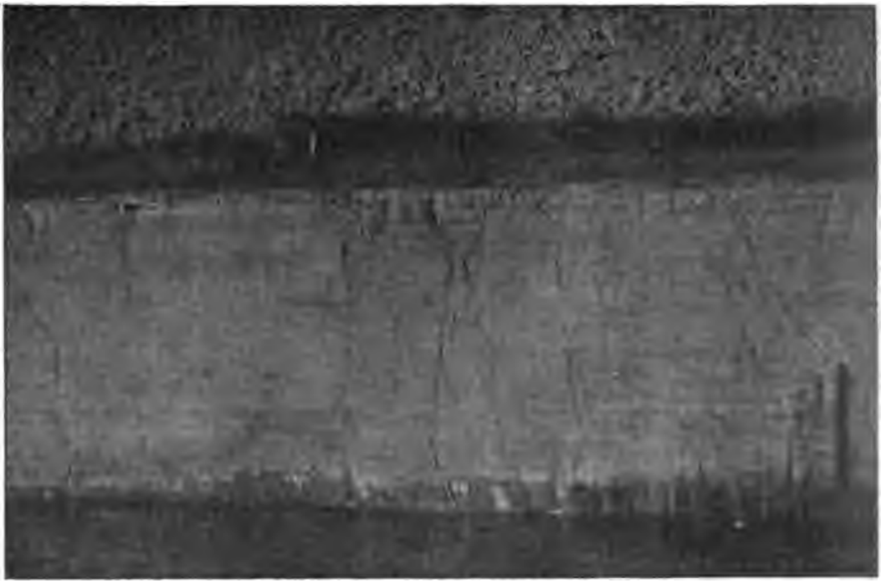


FIG. 6. Showing upturned ledges at fissures. Station 1340, Section 12, Chicago Drainage Canal.

was excavated, develop at the surface of the second lift; after the second lift was excavated they would develop at the top of the third lift; after the third lift was excavated they would develop in the bottom of the channel. Frequently, however, where there were no evidences of them at the surface of the rock, they would develop in the bottom of the channel.

Fig. 7 gives a general view of one of these risings in the bottom of the channel at station 1470 on Sec. 14, about one and one-half miles above Lockport. At the time the excavation was completed at this point and for two or three months thereafter the bottom of the channel was level. The cut was allowed to fill with water, and when it was pumped out several months later this rising and several others were first noticed. Its general direction was approximately at right angles to the center line of the canal. Where the greatest distortion existed it was about fifteen inches high, and only a few inches in some other places. Only the top ledge of rock had raised, leaving a space beneath it nearly equal to the height of the rise.

Fig. 8 is another view of the same rising taken from the bottom of the channel and looking across it.

Fig. 9 is a view taken from the top of the retaining wall—35 feet above the bottom of the channel—and looking across the channel. At the time this picture was taken the bottom of the channel was covered with about six inches of water, making it difficult to show the various small checks on the right side of the

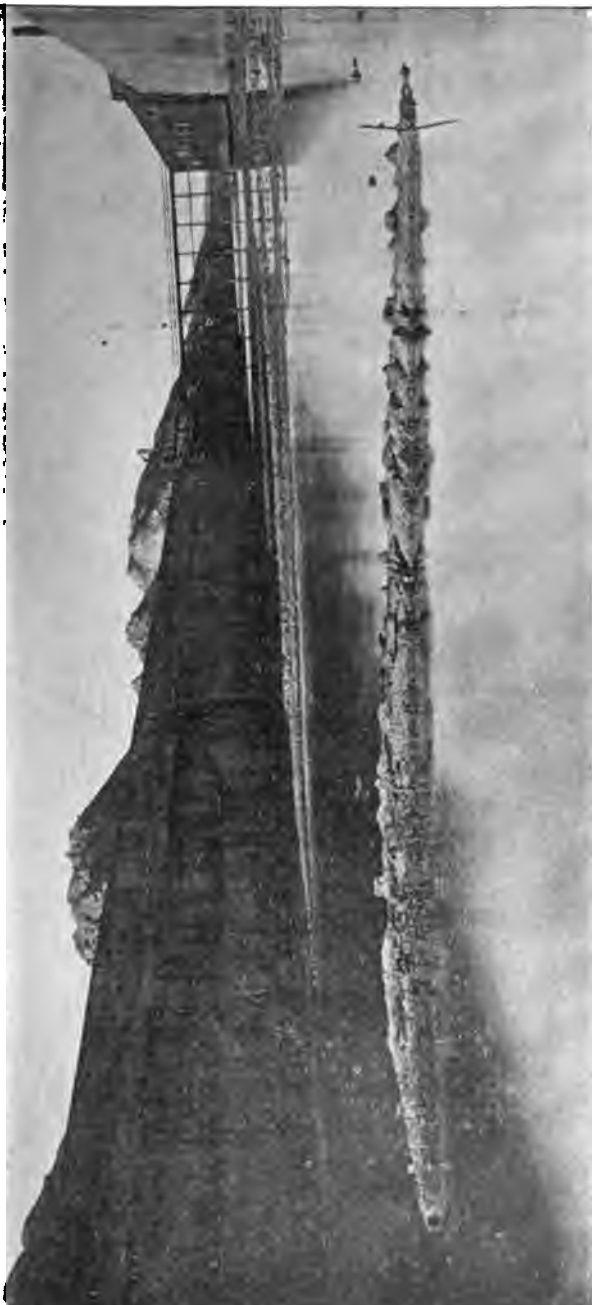


FIG. 7. Looking up stream shows rising in bottom of channel. Station 1470, Section 14, Chicago Drainage Canal.

FIG. 8. Looking across channel showing rising of bottom. Station 1470, Section 14, Chicago Drainage Canal.

FIG. 10. Looking across channel shows rising along line of fissure. Station 1287, Section 11, Chicago Drainage Canal.

FIG. 11. Rising in bottom of channel. Station 1270, Section 11.

channel, and at the left side of the view. It will be noticed that this rising is zigzag across the channel, diverging into several small checks near the west side of the channel and does not follow any vertical seam or fissure.

Fig. 10 shows a rising at station 1,287, Sec. 11, Chicago Drainage Canal, along the line of a one-inch fissure. The top ledge is raised about ten inches and the next lower ledge about six inches.

Fig. 11 shows a rising somewhat different from the others in that there are no evidences of a crack or seam in the rock, but the whole mass of rock, including both first and second ledges, is bulged up. However, the top ledge is bulged up an inch more than the second ledge, leaving a space of that much between them.

In February, 1896, one of these risings occurred on Sec. 8, above Lemont, which was circular in form and about 100 feet in diameter. The top ledge in the bottom of the channel was about eight inches thick, and it raised six inches in two weeks—looking very much like a large blister. The second ledge did not raise, but a space of six inches was left between the ledges. Several risings similar to this occurred on Sec. 3, but no photographs or measurements were taken of them. The ones given here, however, illustrate the two types of risings that have been observed. First, those which occur on each side and adjacent to fissures. Second, those which occur in the form of large blisters without any fissures or seams running through them.

In excavating the drainage canal, the sides of the channel were cut with a channeling machine before any blasting of the rock was done. The cut made by these machines was about two and one-quarter inches at the top and about one and three-quarters inches at the bottom of the cut, the depth of cut usually being about twelve feet. It was frequently observed that the sides of the cut would come closer together in a few days, making its width much less than when first made. It was not uncommon to find the cuts closed to such an extent from Saturday until Monday that a bit two gauges smaller could not be put into it. On Sec. 14 a cut fifty feet long and twelve feet deep closed more than an inch from Nov., 1893, to June, 1894. The usual explanation of this by the workmen was, that "the rock is creeping." The creeping and distortion of the rock is not local, but has been observed in quarries and mines all over the world.

Risings of the same character have been observed in all the stone quarries in the Desplaines valley. The cause for them has been variously ascribed to the effects of the air, the heat of the sun, the water, and to chemical changes taking place in the rock itself. They have developed under a great variety of conditions; when under water so that no great changes of temperature could take place, when exposed to the direct rays of the sun, and when covered with ice and snow. They have also existed in rock

Fig. 12. Showing retaining wall and fractured ledges of foundation. Section 5.

covered with 15 and 20 feet of glacial drift. But whatever the cause may be, it must be admitted that it would require forces of great magnitude to produce these distortions.

What seems to be the best theory is, that they are caused by internal stresses in the rock itself. The outside crust or shell of the earth has cooled off and become hardened and comparatively rigid, while the inner portion is continually cooling and shrinking away from this shell. Gravity acting on all parts of this shell, pulling it toward the center of the earth, produces a compression, stress or force which shows up in the lines of least resistance. These forces are the primary agencies in producing earthquakes and all other disturbances in the earth's crust.

There is an instance of the failure of the retaining wall foundation on Sec. 5 of the canal that may be of some interest in this connection. Fig. 15 is a cross section of the main channel retaining wall, berm and spoil bank at station 995. The dotted horizontal line marked "Glacial Drift Surface" represents the original surface of the ground before any excavation was made. The term "glacial dirft" does not refer to geological glacial drift but glacial drift as defined in the contracts of the Sanitary District, and means all material that is not solid rock. The glacial drift at this point is a very soft black muck with two or three strata of

FIG. 13. Near view of Fig. 12. Section 5, Chicago Drainage Canal.

soft unctuous blue clay mixed with it. The dotted horizontal line below this marked "Natural Rock Surface" represents the surface of the solid rock as it was found when the glacial drift was removed. The retaining wall, berm and spoil bank are all indicated on the map so that they can be readily identified. The glacial drift was excavated for the full width of the channel and retaining wall foundations, removed with cars and locomotives and spread out over the area to the right of the channel—the sides of the excavation taking its natural slope. The rock was then channeled to grade on each side of the channel. Several months after this the loose and soft rock was removed from the foundation of the retaining wall and the wall built on solid rock. The space behind the wall was then filled with broken stone and gravel taken from the main channel excavation, and is marked "backfilling" in Fig. 15. About a year after the wall was completed the rock was excavated and conveyed to the spoil bank by McMyler derricks working on each side of the channel, one-half

FIG. 14. Looking west. Showing condition after failure of foundation and retaining wall. Section 5.

of the excavated material being deposited on each side and about sixty feet from the channel at the toe of the slope.

The rock spoil would settle down into the muck and the muck would bulge up on the berm between the spoil bank and the retaining wall, and is indicated by the dotted line in Fig. 15. This bulging of the black muck occurred on most of Secs. 5 and 6. On September 18, 1896, about one month after the rock had been excavated from station 994 R to station 996+37 R, a small crack was noticed in the solid rock wall near the grade of the channel and nearly parallel to it. By September 21 the crack had enlarged until its width was from three to four inches and some of the natural rock wall had fallen out. A photograph was taken of it at this time and is shown in Fig. 12. The height of the natural rock wall is about fifteen feet above the grade of the channel and the masonry wall, which is founded on the natural rock, is about eighteen feet high, making the total depth from the top of the masonry wall to the grade of the channel about thirty three feet. It will be noticed that this view shows the rock broken in two different places. The crack near the grade of the channel and extending from one of these breaks to the other may also be seen just below the knees of the man in the view. Fig. 13 is a near view of the larger one of these breaks, showing the irregular line of fracture and the splintering of the rock such as would be produced by end pressure. An examination of these fractured ledges showed that the line of fracture

FIG. 17. Showing crack after part of spoil removed.

did not follow a "back" or seam, but about four-fifths of the surface was freshly broken. The crack, above the rock which had fallen out, was from three to four inches wide and extended up to the bottom of the retaining wall, a distance of about seven feet. The crack near the grade of the channel could be traced from station 994 to station 996+37. It was also found to extend from grade up to the wall foundation. This was determined by sounding the face of the wall with a hammer.

Fig. 16 gives cross sections, at the stations indicated, of the natural rock wall, the line of fracture and the masonry wall. At station 994 there was no break in the foundation. At station 994 +50, and at station 995 the crack extended from the grade of the channel to the top of the natural rock, breaking off a wedge-shaped piece of rock. A careful examination of the masonry wall above did not reveal any evidence of breaks in the bed or vertical joints. There was no cracking of stones and the wall was plumb. During September 22 and 23 that portion of the wall which was cracked off continued to fall in a little at a time until

the entire wedge-shaped piece, at 7:30 P. M., had fallen, leaving the masonry wall from station 994 to station 996+37 without any support for the front part of its base. At this time there were no evidences of breaks in the wall itself. About 9 P. M. the wall fell into the channel and the black muck, by the weight of the spoil resting on it, was forced into the channel, covering the broken wall completely and extending more than half way across the channel. The profile of the spoil bank after the failure of the wall is shown by the broken line in Fig. 15. Fig. 14 is a view, looking to the west and down stream, showing the conditions after the failure of the foundation and retaining wall. It will be seen in this view that nearly all of the material which run into the channel was the black muck, with only a small amount of rock spoil on top of it. The rock spoil bank settled down, taking the place formerly occupied by the muck. When the wall failed it pulled a part of the wall at each end out of line. At the down stream end a piece of wall about twenty feet long was moved out toward the channel two feet at the end nearest the break. At the up-stream end about thirty feet of the wall had the appearance of a warped surface and was moved toward the channel about one foot. The break in the foundation ended in a point at station 996+37, but it ended abruptly at the up-stream end at station 994, where there was a vertical seam at an angle of sixty degrees with the center line of the channel.

In Fig. 16 there is a cross section at station 994+10 showing the conditions which existed at the up-stream end of the wall after the slide was removed. The vertical dotted lines at the front and back of the wall indicate the original position of the wall and the break is shown up to and behind the wall. The width of the crack shown here is about ten inches, part of which is evidently due to the pulling effect of that part of the wall which failed. Ten feet farther up stream at station 994 the crack ends abruptly. Fig. 17 is a view taken at station 994+10 before the slide was entirely removed and shows the crack very plainly at some points, but does not show it continuously on account of the spoil not being entirely removed. The McMyler derrick, weighing about one hundred tons, shown in the middle of the view, Fig. 14, was placed on top of the wall and back filling at the down-stream end of the slide and used in removing the material from the channel. By referring to Fig. 16 it will be seen that the wall was built on a level foundation in some cases, as at station 996, and in other instances the foundation was in steps with horizontal treads and vertical rises, as at station 994, the rise never being greater than the tread.

The point of greatest interest to the engineer is to determine what caused the failure of the foundation and wall. The question is presented with the desire that some of the members will give a satisfactory explanation. There have been three suggestions made by various people as to the cause.

1st. It was due to the wall not being founded upon a perfectly level foundation throughout. Unless the known principles of mechanics are at fault this cannot be the cause.

2nd. It was due to the pressure of the spoil and back-filling against the wall.

Beyond question there was an increased pressure on the wall, transmitted through the muck from the rock spoil deposited on it. This pressure would tend to overturn the wall on its base and crush the stones in the bottom courses of the wall or chip off the rock foundation, and the top of the wall would have leaned toward the channel. None of these conditions existed. It would seem that any pressure acting behind the wall which was great enough to destroy the foundation would be great enough to immediately overturn the wall after one-half of its foundation was gone. The wall stood, without any evidences of weakening, for more than three days after the foundation had failed.

3d. The failure was due to the action of internal stresses in the rock.

The forces which produced the distortions of the rock referred to in the first part of this paper are certainly great enough to be the sole cause of this failure of foundation. And the actions of the break were such as to justify the belief that these forces were at work at this point. It is probable that they, in conjunction with the increased pressure behind the wall, were the cause of the failure. But it is not believed that the pressure behind the wall was, acting alone, great enough to do the work.

DISCUSSION.

Mr. Cooley: In the risings which occur along the line of a fissure, is there any closing of the fissure?

Mr. Harrison: Yes, sir. The fissures are filled with clay, and the first indication of a movement in the rock is shown by the clay being squeezed out of the fissure. Soon after this the rock would buckle.

Mr. Cooley: How wide were the fissures before they began to close?

Mr. Harrison: They varied from almost nothing to three or four inches.

Mr. Powell: Of what does the back-filling consist?

Mr. Harrison: Broken stone and gravel taken from the channel and is shown in Fig. 17.

Mr. Powell: Does the black muck extend to the solid rock surface?

Mr. Harrison: The rock is covered with from one to three feet of geological glacial drift, and the muck overlies that.

Mr. Powell: Does the bank contain much spoil?

Mr. Harrison: The spoil bank on this part of Sec. 5, and nearly all of Sec. 6, is composed principally of rock. The same

rising of the muck occurred on. Sec. 6. It was frequently twelve or fifteen feet high. That shown by the dotted line in Fig. 15 is only five or six feet high.

Mr. Powell: What is the height of the solid rock from the grade of the channel to the base of the retaining wall? In Fig. 12 is a man standing near the wall which would indicate that it is perhaps eight or nine feet.

Mr. Harrison: The height of the man is about the same as the height of the top of the break, and the base of the retaining wall is six or seven feet above that. The average height of the masonry wall at this point is about eighteen feet and the natural rock about fifteen feet, making the total height thirty-three feet.

Mr. Powell: Was the wall on a tangent or curve?

Mr. Harrison: On a curve of thirty minutes. The pressure of spoil bank was against the concave side. The variation of the curve from a tangent would be slight in an hundred feet.

The Chair: I might make a remark or two with regard to these questions myself, and then I would like to ask Mr. Harrison two or three questions. There is a point or two with regard to the question of the failure of this wall which is of interest. One which I think of now: Mr. Harrison has shown how a wedge of rock has been displaced underneath the wall. There is a surface demarkation between the wedge that is split away and the solid rock which is left in place. The break was along that surface, and some question may arise as to where the stress came from that caused that break. Some light might be thrown upon that subject by considering the amount of stress that is necessary to cause that break. If the surface between the solid rock left in place and the wedge, was one offering little resistance to displacement of the rock on either side, there might be some reason for thinking the weight of the wall caused the break. An examination of the surface as far as it was possible (and that examination was over the surface where the rock fell) showed the character of the rock to very solid, perhaps as solid as any along the line of the drainage canal; the surface sheared was very large, and the amount of stress necessary to cause that shear must have been very much greater than anything that could have been caused by the weight of the wall and the overturning of the muck behind it. For each running foot of wall there was perhaps ten square feet of rock shear formed, and it seems to be entirely beyond possibility that the weight of the wall or any load from the wall could cause such shearing. That being the case, we have to stay behind the arguments advanced by Mr. Harrison as to the natura 1 istortion o the rock, and it seems probable that was the cause of the fracture.

Now, in that connection it is interesting to call attention to a somewhat similar case that happened on section 7 about a year ago in which a piece of retaining wall failed when there was nothing behind it and nothing in front; the only way it was possible to bring stress on the wall would be from below or from

the solid rock at either end. That would unquestionably be a case of failure of the wall due to the displacement of the rock.

Mr. Harrison: The case referred to by the President is one of unusual interest. The masonry wall was about fourteen feet high, built on natural rock foundation and each end of it against solid rock, the up-stream end being vertical and the down-stream sloping off. The length of the base was 105 ft. and the top 140 ft. The twenty-five feet of the up-stream end was the part which failed. Before the wall was built, the rock in the channel had been removed, and the filling behind the wall had not been made at the time of the failure. No work was being done near enough to the wall to have any effect on it. The failure was first noticed on Friday, Nov. 1st, 1895. A careful examination showed that a number of stone in the wall were crushed, more of the crushed stone being found near the bottom than any other place. When the wall was torn down, some of these stone were found to be broken into a dozen pieces. There was a vertical longitudinal crack about ten feet long and a half-inch wide in the top of the wall. The face of the wall had moved toward the channel and the back of it from the channel. This break was evidently due to end pressure. Where did this pressure come from? It is probable that the force of compression, previously referred to, existed at this point and was materially assisted by the general shaking of the earth by the earthquake which occurred on the night of Oct. 31st. At any rate, the wall was sound on Thursday, and was damaged Friday morning.

Mr. Rohrer: Was that when the Western Stone Company had quarried into the main channel?

Mr. Harrison: Yes, sir.

Mr. Rohrer: This quarry had been worked out prior to 1892, when the Sanitary District began work. The wall was not built until 1895, fully three years after the quarry excavation had been made. Is it not probable the rock had adjusted itself to the new conditions before the wall was built?

Mr. Harrison: It certainly would to some extent, but it is also possible that the stresses in the rock do not remain constant and they may have been augmented after the building of the wall and materially assisted by the trembling due to the earthquake.

Mr. Beardsley: Is it not possible that the blasting in front of the wall had something to do with it?

Mr. Harrison: I think not. A blast would break up from eight to ten running feet of rock. If the blast at a given point should loosen the natural rock wall, the next blast would knock the loose pieces out. But in this case the blasting had proceeded more than an hundred feet beyond where the failure occurred.

III.

MOUNT WOOD AND TOP MILL TUNNELS ON EASTERN APPROACH TO OHIO RIVER BRIDGE.

Wheeling Bridge and Terminal Railway.

By W. J. Yoder, C. E., Mem. W. S. E.

Read January 20, 1897.

LOCATION AND GENERAL DESCRIPTION.

The tunnels herein described are within the northern city limits of Wheeling, West Virginia, and on the Wheeling Bridge and Terminal Railway, a short connecting line which is projected to furnish additional facilities for railway transportation across the Ohio River and to insure new and better connections with existing roads on either side.

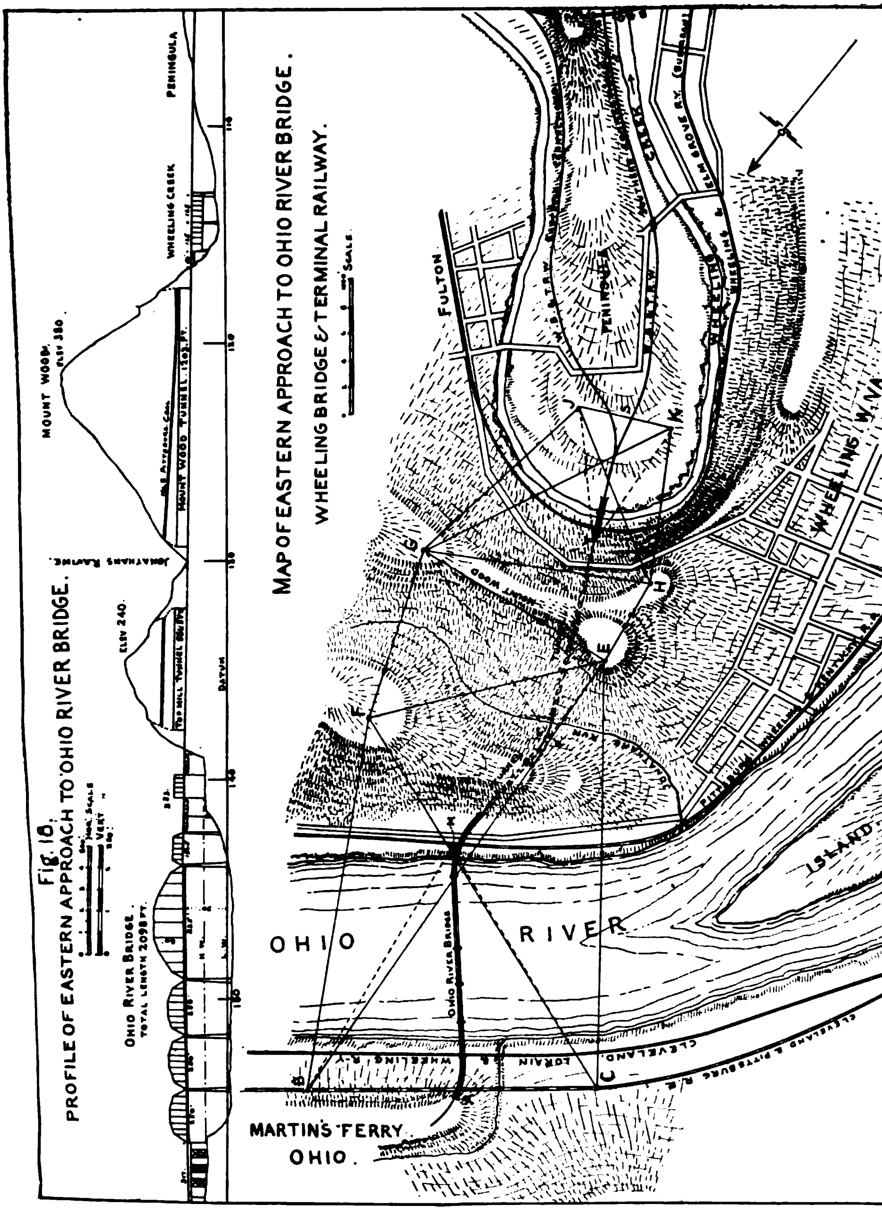
The location of the tunnels was determined by the selection of a site for the Ohio River Bridge, and the general requirements of a line to connect with the other roads at points north, east and south of the city.

The Ohio River at Wheeling flows in a southerly direction in a rather narrow valley, from which on the West Virginia side the hills rise quite abruptly to a height of from three to six hundred feet. By referring to Fig. 18, it will be seen that Wheeling Creek, a stream flowing from the east and emptying into the Ohio River near the center of the city, makes a sharp bend, forming what is called the "Peninsula."

The direct distance from the east shore of the Ohio River at the selected bridge site to the north bank of Wheeling Creek at the northern extremity of the Peninsula is about 2,700 feet; between these two points the surface of the ground is very irregular, rising in two distinct hills, Mount Wood and Top Mill hill separated by Jonathan's Ravine; these hills are 380 and 240 feet in height, respectively.

The elevation of the bridge, 90 feet above low water, was such that a uniform descending grade of 46 feet per mile was necessary to obtain an undercrossing of the Baltimore & Ohio R. R. on the Peninsula. See Fig. 18.

The deviation to the right from a direct line between the Ohio River Bridge and the Peninsula was made to establish a station in Jonathan's Ravine at some future time to accommodate the North Wheeling traffic. Both tunnels are on tangents which intersect in Jonathan's Ravine at "P" Fig. 18, forming an angle of 27 degrees and 34¼ minutes. These tangents are connected by a 10 degree curve to the left, which is 275 feet long, and extends


PROFILE OF EASTERN APPROACH TO OHIO RIVER BRIDGE.
MOUNT WOOD.
ELEV 380
ELEV 240
JONATHANS RAVINE
MOUNT WOOD TUNNEL 1203 FT.
WHEELING CREEK
PENINSULA
DATUM
OHIO RIVER BRIDGE.
TOTAL LENGTH 2098 FT.
MAP OF EASTERN APPROACH TO OHIO RIVER BRIDGE.
WHEELING BRIDGE & TERMINAL RAILWAY.
SCALE
FULTON
PENINSULA
WHEELING W.VA.
ISLAND
OHIO RIVER
OHIO RIVER BRIDGE
CLEVELAND LORAIN & WHEELING R.Y.
CLEVELAND & PITTSBURG R.R.
MARTIN'S FERRY
OHIO.
Fig. 18.

from the Northwest portal of Mount Wood Tunnel to South portal of Top Mill Tunnel. The tangent through the Top Mill Tunnel extends 175 feet north from North portal, where a 9 degree and 26 minute curve swings to the left 432 feet to East End of the Channel Span of the Ohio River Bridge.

GEOLOGY AND CHARACTER OF MATERIAL.

Geologically the tunnels are located at the top of "The barren measures" of the "Carboniferous Formation" and pass through a stratum of grey argellaceous shale lying just under the No. 8 Pittsburg Coal Vein.

The shale disintegrates rapidly on exposure to the elements and is non-supporting.

In the Top Mill Tunnel the shale was full of vertical dry seams which caused the material to break into angular masses leaving cavities outside the symmetrical section. (See Fig. 27.) The consequent irregular roof not only required considerable packing, but will have a very damaging effect on the timbering in case of sudden and unequal pressure from overhead.

In Mount Wood tunnel the shale was interspersed with bands of light grey sandstone varying from several inches to six feet in thickness. The shale, being free from the vertical dry seams, more symmetrical sections were obtained. (See Fig. 28.)

Most of the bottom of the tunnel is sandstone, which affords a good foundation for the timbering. It is probable that the decomposed shale outside the timber lining with the moisture that is present will form a clay-like paste, excluding the air and stopping further disintegration.

Plate I shows a geological section.

Some very fine specimens of vegetable fossil were found in Jonathan's Ravine. About ten varieties, including tree ferns, mosses, fronds and calamites. (See Fig. 42.)

SPECIFICATIONS.

"At the approaches to rock tunnels, face cuttings having such width and slopes as may be required shall be carried to the points indicated by the Engineer.

"The material excavated, and also that taken from the tunnels shall be removed and placed in the railway embankment or elsewhere as directed by the Engineer.

"The tunnels shall be excavated for a double track and shall be made to conform to the alignment and grades furnished from time to time by the Engineer. The cross section of the tunnels shall be such as to admit of being lined with brick or masonry, having a clear height from top of rail elevation not less than nineteen (19) feet over the center of the track, and widths in the clear not less than twenty-seven (27) feet.

PERMANENT WALLS.

"If the material found in excavating is anywhere of such char-

acter that it may be safely used in place for side walls or roof of the tunnel without any reinforcement or lining of masonry, the contractors in blasting shall exercise great care to avoid loosening or displacing any such material beyond the side lines given by the Engineer, and if required at any time they shall remove the rock with wedges or by using small charges of common powder.

TIMBERING.

"Where the material at the sides or top of the excavation is not firm and suitable to form permanent and safe side wall or roof for the tunnel, the excavation shall be of such width and height as to leave space outside the limits required for the above mentioned masonry lining, for the introduction of the necessary side supports and roof timbers, which shall be of such size and character as the Engineer may direct. These timbers are to be provided, framed and placed by the Contractors according to drawings and directions furnished them as the work progresses, by the Engineer.

CARE OF EMPLOYEES.

"The Contractors shall at all times exercise the greatest possible care to prevent accidents to workmen from the falling rock or from careless handling of timbers or the use of explosives.

"Proper ventilation shall at all times be provided and the Contractors shall, throughout the whole work, conform to any existing State Law or rules that obtain in tunneling or mining operations and shall at all times submit to any customary or required State inspection.

SOFT BED.

"If the material below sub-grade of the tunnel is anywhere loose or soft and unsuitable for a road bed it shall be removed by the Contractors and good material substituted in its place."

METHODS OF CONSTRUCTION.

After considering first cost, character of material and probable absence of water, it was decided to use the "Block System" of timbering instead of lining the tunnels at once with masonry. The excavated section is large enough to receive the proposed masonry and the permanent timbering, as shown by Fig. 30, and as usual was divided into two parts—the driving of the heading and taking out the bench—except in the S. E. end of the Mount Wood Tunnel where a heading 10×12 feet was first driven 155 feet and afterwards enlarged, and from this point on for 110 feet, where the condition of the roof necessitated a small heading or drift and side enlargements following, and in north end of Top Mill Tunnel where, at the beginning, a 10×13.5 ft. heading was driven and the sides afterward enlarged.

The arch timbering was kept up close to the face of the heading, usually within from 10 to 30 feet, and never more than 50

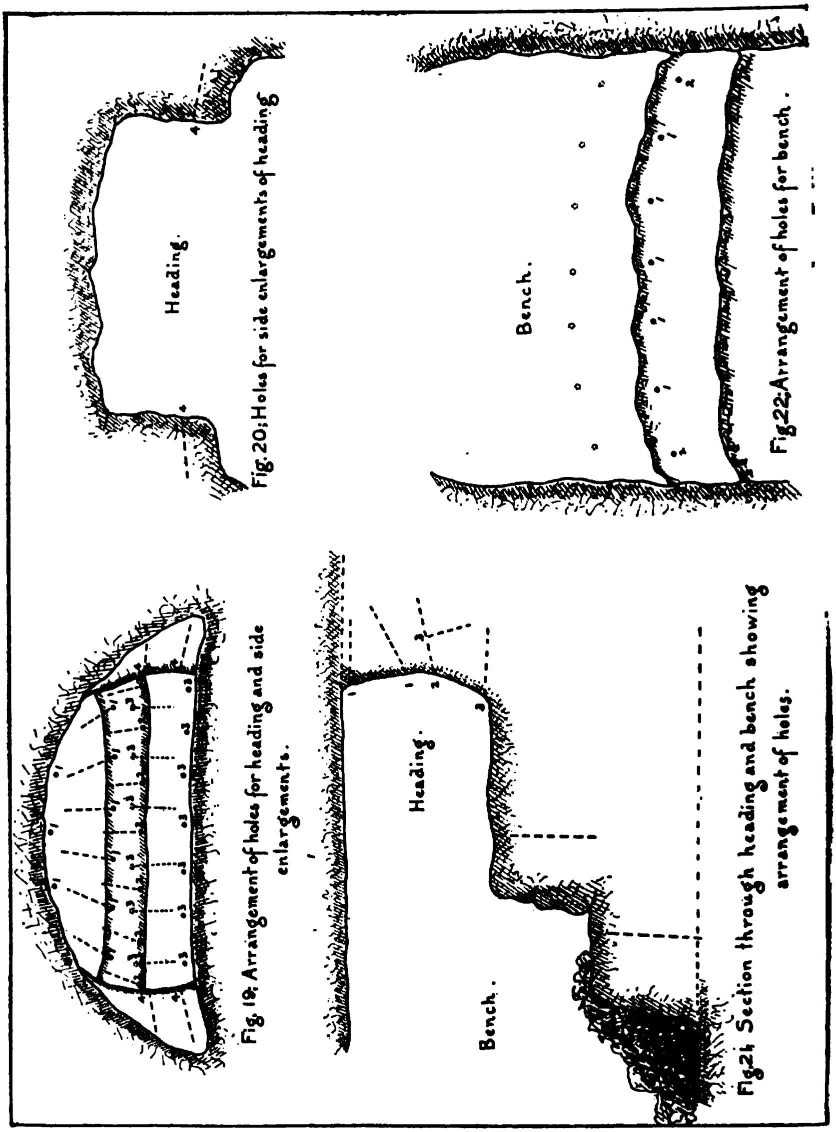


Fig. 19. Arrangement of holes for heading and side enlargements.

Fig. 20: Holes for side enlargements of heading.

Fig. 21. Section through heading and bench showing arrangement of holes.

Fig. 22: Arrangement of holes for bench.

feet. Facing and lacing boards were temporarily spiked on the timbering to protect and keep it from being mutilated and displaced; they were torn off as new timbering was added.

All drilling was done by hand. The general arrangements and usual number of holes is shown by Figs. 19–21. The order of the firing is indicated by number.

Holes No. 1—were from 5 to 6 feet deep each. Holes No. 2—were usually 5 feet each, and No. 3—varied from 3 to 5 feet each. The 33 holes as shown by Fig. 19, aggregated about 160 lineal feet, and required about 60 lbs. of 40 per cent Forcite to load them.

The usual effect of a blast was to displace about twenty-five cubic yards, corresponding to an advance of 2½ feet.

The heading gang usually consisted of 1 foreman, 14 drillers, 12 muckers and 1 nipper. About 25 lineal feet of drilling was considered a day's work for two men. The material from the headings was loaded and wheeled in iron barrows to the top of a scaffold or traveler (Figs. 35-36) and dumped down chutes on either side, or at the end into dump cars.

The heading gang timbered and packed the arch; two shifts per week were necessary to get the arch timbers in place. So that only ten shifts per week worked in advancing the heading. Work was carried on in two ten-hour shifts.

The ventilation was very good, except when the temperature in and outside the tunnel was about the same. The only serious difficulty encountered was a bad roof in part of the Southeast heading of Mount Wood Tunnel. By referring to Plate No. I it will be seen that a vein of coal (No. 8 Pittsburg) is at an elevation of 109 feet, or four feet above the lagging at the Southeast portal.

At the northwest portal the coal vein is at an elevation of 139, or 21 feet abovet he lagging. The coal from this vein having been mostly removed and the mines abandoned for some time, they were practically inaccessible from the heavv falls, debris and water. It was found at a distance of about 150 feet from the S. E. portal that the grade of the roof of the tunnel was approaching the bottom of the old mine, owing to a dip of the coal vein to the north. 156 feet from the portal the rock overhead was first broken through, letting down fine coal mixed with fire clay and water. After two or three falls occurred of larger proportions but of similar material, it became evident that the material in the old mine would require support as the grade of the tunnel brought the roof of the heading into the bottom of the mine. (Figs. 23–26.) From this point on for 110 feet, a small heading or drift with side enlargements, by the cap and poling board method, was successfully employed and was as follows :

An oak cap or collar 12″ × 12″ × 16′ was placed across the heading and the ends blocked up on the rock until the bottom of the cap was about two feet above the grade line of the regular lagging. Over this cap 3″ oak poling boards 6 feet long were

driven through the debris with a slope upwards of about 1 in 12. (Fig. 24.)

As the material was removed from under them, the advanced ends were kept up by small boards set on ends as props. When the material was sufficiently removed another cap was placed under the farther end of the poling boards or three or four feet from the first cap and blocked. On top of this cap wedges were placed and above the wedges a 2″ oak cross board; the wedges were then driven and the cross board forced up to the poling boards or until a 4″ space was left between the cross board and the top of the cap. The small props were then withdrawn from under and the poling boards let down on the cross board. More poling boards were driven over the cap or between it and the cross board in the 4″ space left.

Then the material was removed from under the boards as before and another cap introduced.

After placing two or three caps it was necessary to remove the rock from under as the space between the top of the rock and the bottom of the poling boards was too limited to work in. When the rock had been removed, more caps were placed and poling boards driven. This was continued until the rock, with careful working, was thick enough (3 ft.) above the grade line of the regular lagging to support the material above.

In the side enlargements of this portion, the method used was as follows:

Posts were placed under the caps and the sides shingled with 3″ oak boards 6 feet long. (Fig. 25.) The enlargement was then proceeded with. When advanced far enough (about 16 ft.) for wall plates. The arch timbers were then erected and the space between the poling boards and the top of the lagging filled with blocking and tightly wedged. As the arch timbering came up to the temporary posts supporting the caps, bars 8″ × 12″ × 12′ were placed on the arches as at H Fig. 25, passing under and supporting the caps and propped at the end; then the arch timbering was continued until another post was encountered and bars were again used as before.

The arch timbering under this part of the roof has since shown signs of pressure. The joints in some places opening from ¼″ to 1″ and the key piece splitting as in Fig. 33, and letting down the crown of the arch from 2″ to 6″. Extra arches of timber have been put in between the old sets at these places.

The removal of the "bench" followed usually from 50 to 75 feet behind the heading, and was worked in two lifts of about 8 feet each. It was necessary to use care in removing the rock on either side under or near the wall plates. The plumb posts and side lagging and packing was kept close up to the face of the bench; lacing boards were spiked to the bottom of the plumb post or blocks placed between them close up to the bench where they were in danger of being blown down. Care was also taken

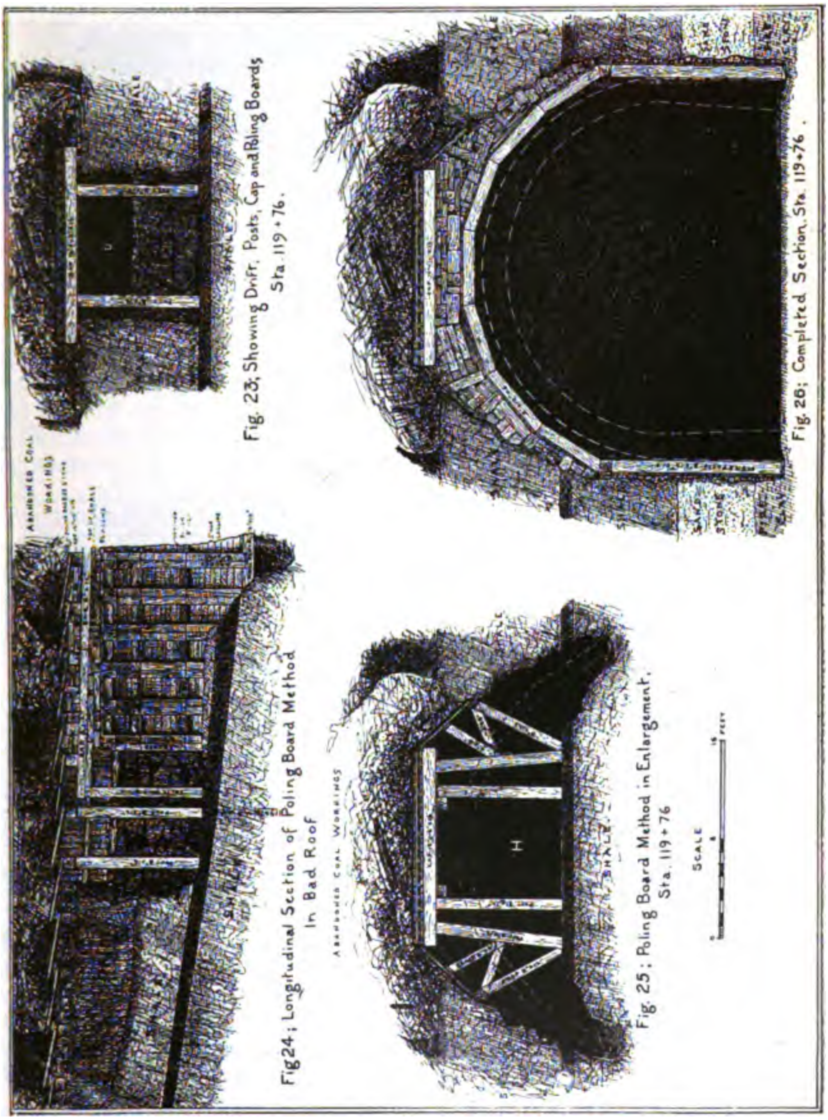


Fig. 23; Showing Drift, Posts, Cap and Poling Boards Sta. 119+76.

Fig 24; Longitudinal Section of Poling Board Method In Bad Roof

Fig. 25; Poling Board Method in Enlargement. Sta. 119+76

Fig. 26; Completed Section, Sta. 119+76.

Fig. 27; Section of Heading and Enlargement, Mount Wood Tunnel.

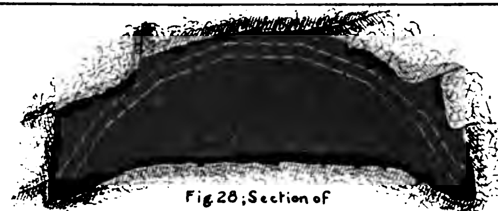
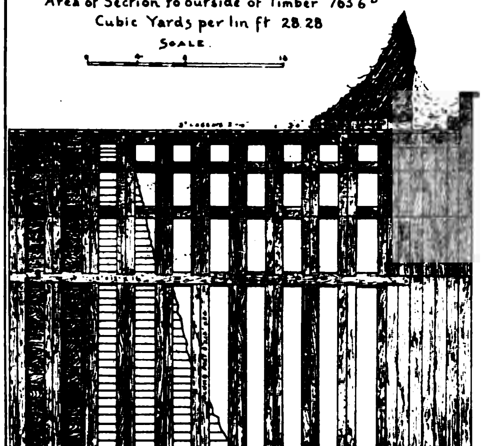
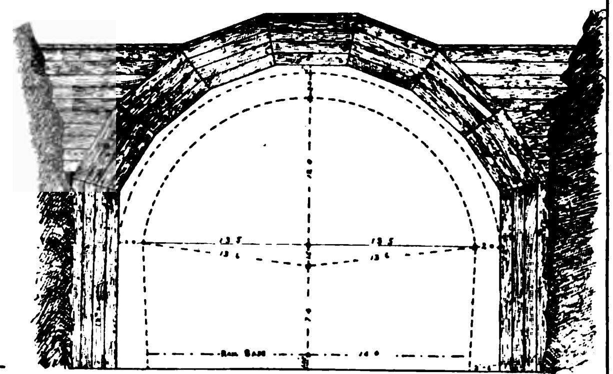


Fig 28; Section of Heading and Enlargement. Top Mill Tunnel.

BILL OF TIMBER		FT. B. M.
2 Wall Plates	12" x 12" x 16	384
10 Arches	8" x 12" x 42'	3360
20 Plumb Posts	8" x 12" x 14'	2240
30 Notched Blocks	8" x 12" x 2'-10"	680
Top Lagging	3" x 38' x 15'	1710
Side Lagging	3" x 14' x 15' x 2	1260
	Total	9634
Average per Lineal Foot.		642

Area of Section to outside of Timber 763 6□
Cubic Yards per lin ft 28.28
Scale.





Longitudinal Section of Timber Lining and Portal. Figs. 29 & 30. Timber Portal and Section of Proposed Masonry Lining

to keep any space between the wall plates and the rock behind well blocked. As the plumb posts were placed in position under the wall plates and wedged up to the same, a block or piece of lagging was placed between the wall plates and the plumb posts where they join and the rock behind (See Fig. 34) and wedged to keep the wall plates and posts from being displaced, and the consequent spreading of the arch. Iron clamps at the joints in the wall plates, as shown in Fig. 31, were satisfactorily introduced.

After the benches were advanced 40 or 50 feet, they were taken off and carried forward to be used again.

The number and position of holes in the bench as well as the order of firing is shown by Figs. 21 and 22. They were usually 8′ deep. Churn drills were used to put down Nos. 1 and 2 and hammers for corner holes or block holes, in masses too large to sledge.

All the material was loaded from grade into dump cars. The scaffold cars (Figs. 35 and 36) were pushed back 60 to 100 feet before firing. The bench force usually consisted of 1 foreman, 6 drillers, 18 muckers, 2 drivers, 3 dump-men and 1 nipper.

The material from the tunnels was disposed of in the following manner: All the material from the north approach and Top Mill tunnel was hauled in dump cars and dumped down a chute from the top of the east abutment of the Ohio River Bridge into flat cars furnished by the P. C. & St. L. R. R. Co., who disposed of the material in widening their embankments and filling in trestles, etc., along the Ohio River.

All material from the south approach of Top Mill tunnel and N. W. end of Mount Wood tunnel was hauled in dump cars by mules, down a tramway on the north side of "Jonathan's Ravine" crossing over Main street on a temporary trestle and dumped down a zigzag chute into flat cars and disposed of in the same manner as mentioned before. All the material from the south-east end of Mount Wood tunnel was hauled over Wheeling Creek on a temporary trestle and deposited in embankment. The average hauls were:

From S. E. Portal of Mount Wood Tunnel	870 feet.
" N. W. " " " " "	1,140 "
" South Approach Cut to Top Mill Tunnel	810 "
" North Heading of Top Mill Tunnel	225 "

TIMBERING.

The lining of both tunnels is of white oak throughout and the block system was used. (Figs. 29 and 30).

The arches were composed of seven segments, each 8″ × 12″ × 6′ long; two of these arches were placed together so as to form one set, which would be equivalent to one arch of 12″ × 16″, with the advantage, however, that by using two sets and cutting the timber 8″ × 12″ instead of one 12″ × 16″, much better timber was obtained. The pieces were more easily erected and fitted, and should it be desired, one arch can be withdrawn when weakened

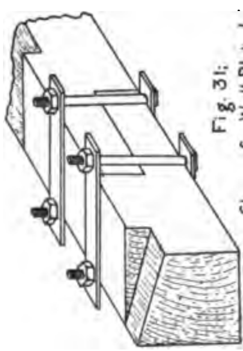


Fig. 31; Clamps for Wall Plate Joints.

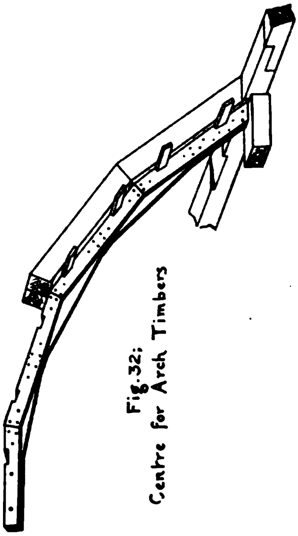


Fig. 32; Centre for Arch Timbers

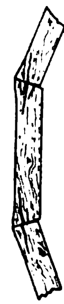


Fig. 33.

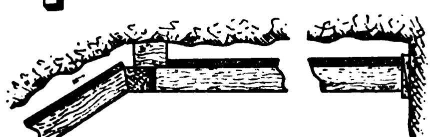


Fig. 34.

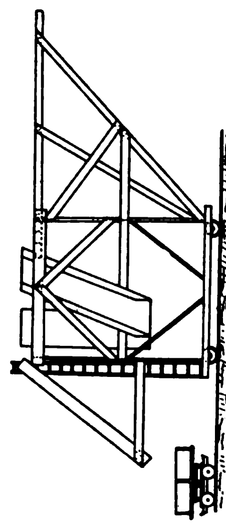


Fig. 35; Scaffold Car, Side View.

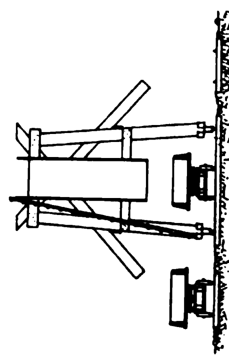


Fig. 36; Scaffold Car, End View.

by decay and a new one substituted, as it was contemplated that the rate of decay would not be uniform throughout the tunnels and it might be desirable to replace and maintain the timber lining for some time to come. The arches were supported on wall plates 12"×12"×16'; there were five sets on each pair of wall plates (or ten independent arches). The sets were spaced 3 feet centers, the space between being 20", and 8"×12" notched blocks were introduced at joints to act as longitudinal braces and keep them separated. The wall plates rested on ten plumb posts 8"×12"×14' and also placed in sets under the arches. 3" lagging was used on the arches and on the sides.

This plan of timbering was used throughout except at the portals where 12"x12" arch timbers were placed close together and drift bolted, so as to form a solid timber arch. The posts were treated in the same manner. A timber parapet was built on the top of this solid arch as shown in Figs. 29 and 30.

As to the life of this timber lining, it is hard to conjecture. I examined it after four years' use and could find no decay even in that portion that is drenched with water, strongly impregnated with sulphur from the old mine overhead. And the portions alternately wet and dry.

It is probable that it will last from 10 to 15 years, as the conditions are more or less favorable, before it will have to be replaced. If any one present has had experience with the use of white oak timber under similar conditions either in tunnels or mines and can give information on this point, it will be of much interest.

In erecting the arch timbers a centering was used, made of 1" pine in three layers, the center pieces breaking joint with the other two. (Fig. 32.) This centering was joined in the middle with two bolts, the nuts being cranks to facilitate the putting up and taking down of the centering. No dowel plates or pins were used in the arching. Wooden dowels 1" in diam., driven in ⅞" holes, were used at joints of wall plates.

BILL OF TIMBER.

Mount Wood Tunnel.		*Ft. B. M.*	
841	Arches. 8"×12"×42'	282,576	
14	" 12"×12"×42'	7,056	
855	"		289,632
1650	Plumb Posts 8"×12"×14'		184,800
158	Wall Plates 12"×12"×16'	30,336	
2	" " 12"×12"×14'	336	
2	" " 12"×12"× 5'	120	
162	" "		30,792
	Side lagging 3"×28'×1203'	101,052	
	Top " 3"×42'×1203'	151,578	
			252,630
2374	Notched Blocks 8"×12"×2'6"		47,480
	Total B. M		805,332

$\frac{805332}{1203}$ = 669.4 ft. B. M. per lineal foot.

PORTALS.

In the plan for each portal, the bill of material is as follows:

		Ft. B. M.	
42	Pieces 12"×12"×6'	3,024	
14	" 12"×12"×6'6"	1,092	
7	" 12"×12"×7'	588	
7	" 12"×12"×7'6"	630	
20	Posts 12"×12"×16'	6,400	
3"	Lagging 6'×42'	756	
46	lin. ft. 4"×16"	245	
		12,735	
	Portals	2	
			25,470
			805,332
	Grand total		830,802

Bolts.

22	Drift Bolts 1"×24"	Wt.	116.38	Lbs.
144	" " 1"×30"	"	952.20	"
44	" " 1"×20"	"	193.90	"
14	" " 1"× 8"	"	24.67	"
224	" " Total	"	1,287.15	"

Top Mill Tunnel.

		Ft. B. M.	
367	Arches 8"×12"×42'	123,312	
3	" 12"×12"×42'	1,512	
370	"		124,824
736	Posts 8"×12"×14'	82,433	
4	" 12"×12"×14'	672	
740	"		83,105
74	Oak Wall Plates 12"×12"×16'		14,208
	Side Lagging 556.5'×3"×28'	46,746	
	Top " 556.5"×3"×42'	70,119	
			116,865
1098	Notched Blocks 8"×12'×2'6"		21,960
	Total		360,961

$$\frac{360961}{556.5'} = 648.68 \text{ ft. B. M. per Lineal ft.}$$

Portals, same as Mount Wood	25,470
Mount Wood	830,802
Grand Total	1,217,233

NOTES OF PROGRESS AND CONSTRUCTION.

The following tables, Nos. 1, 2 and 3 give the progress in detail for each tunnel. On plate I is shown a progress profile.

MOUNT WOOD TUNNEL.

S. E. Approach Cutting began	Dec. 24, 1888	
Cubic-yards Excavation		5,461
S. E. Heading began	Mar. 20, 1889	
" " finished	Nov. 7, 1889	
S. E. Bench began	May 7, 1889	
" " finished	Dec. 3, 1889	

NO. I.

PROGRESS TABLE

MOUNT WOOD TUNNEL.

SOUTH EAST HEADING.

DATE 1889.	LINEAL FEET.	CUBIC YARDS.	TOTAL LINEAL FEET.	TOTAL CUBIC YARDS.	SIDE ENLARGEMENT LINEAL FEET.	SIDE ENLARGEMENT CUBIC YARDS.	REMARKS.
MARCH 20TH. TO MARCH 30TH	83.0	387.0	83.0	387.0			HEADING 10'×12.5'
MARCH 30TH. TO MAY 6TH.	72.0	307.0	155.0	694.0	60.0	327.0	" 10'×11.5'
MAY 6TH. TO JUNE 3RD	10.5	107.0	165.5	801.0	95.0	560.0	BAD ROOF.
JUNE 3RD. TO JUNE 29TH	34.5	352.0	200.0	1153.0			" "
JUNE 29TH. TO JULY 31ST.	75.0	765.0	275.0	1918.0			" "
JULY 31ST. TO SEPT. 2ND.	95.0	969.0	370.0	2887.0			
SEPT 2ND. TO SEPT. 30TH	97.0	989.4	467.0	3876.4			
SEPT 30TH. TO OCT. 31ST.	115.5	1178.0	582.5	5054.4			
OCT. 31ST. TO NOV. 1ST.	20.5	80.0	603.0	5134.4			HEADINGS MET AT 7 P.M. NOV. 7TH.
NOV. 1ST. TO NOV. 7TH.					20.5	129.0	

MAXIMUM MONTHLY PROGRESS, OCTOBER = 115.0 LINL. FT.
AVERAGE " " 82.26 " "
MAXIMUM WEEKLY " OCT. 21ST TO 28TH = 35.0 " "

SOUTH EAST BENCH.

DATE 1889	LINEAL FEET	CUBIC YARDS.	TOTAL LINEAL FEET.	TOTAL CUBIC YARDS.	REMARKS.
MAY 7TH. TO JUNE 3RD.	83.5	1505.5	83.5	1505.5	
JUNE 3RD. TO JUNE 29TH	86.5	1559.6	170.0	3065.1	
JUNE 29TH. TO JULY 31ST	64.0	1153.9	234.0	4219.0	PROGRESS RETARDED BY HEADING.
JULY 31ST. TO SEPT 2ND	86.0	1550.6	320.0	5769.6	"
SEPT 2ND TO SEPT 30TH	101.0	1821.0	421.0	7590.6	
SEPT 30TH. TO NOV. 1ST.	102.5	1848.1	523.5	9438.7	
NOV. 1ST. TO DEC. 3RD.	105.0	1893.1	628.5	11331.8	

MAXIMUM MONTHLY PROGRESS NOV. = 105.0 LIN. FT.
AVERAGE " " 89.8 " "

AVERAGE CUBIC YARDS PER LIN. FT. OF HEADING & ENLARGEMENT = 10.2
AVERAGE CUBIC YARDS PER LIN. FT. OF BENCH = 18.03.

No. 2.

PROGRESS TABLE

MOUNT WOOD TUNNEL.

NORTH WEST HEADING.

DATE. 1889.	LINEAL FEET.	CUBIC YARDS.	TOTAL		SIDE ENLARGEMENT		REMARKS.
			LINEAL FEET.	CUBIC YARDS.	LINEAL FEET.	CUBIC YARDS.	
APRIL 8TH. TO MAY 6TH.	46.0	230.0	46.0	230.0	46.0	239.2	HEADING 10'x 13.5'
MAY 6TH. TO JUNE 3RD.	44.0	448.8	90.0	678.8			
JUNE 3RD. TO JUNE 29TH.	100.0	1020.0	190.0	1698.8			
JUNE 29TH. TO JULY 31ST.	95.0	969.0	285.0	2667.8			
JULY 31ST. TO SEPT 2ND.	74.5	759.9	359.5	3427.7			NO NIGHT SHIFT DURING AUGUST.
SEPT 2ND TO SEPT 30TH	96.5	984.3	456.0	4412.0			
SEPT 30TH. TO OCT. 31ST.	130.0	1326.0	586.0	5738.0			
OCT. 31ST. TO NOV. 1ST.	14.0	60.0	600.0	5798.0			HEADINGS MET AT 7 P.M. NOV. 1ST.
NOV 1ST. TO NOV 7TH.					14.0	82.8	

MAXIMUM MONTHLY PROGRESS OCTOBER = 130.0 LIN. FT.
AVERAGE " " 85.7 " "
MAXIMUM WEEKLY " OCT 1ST. TO 7TH. = 33.0 " "

NORTH WEST BENCH.

DATE. 1889.	LINEAL FEET.	CUBIC YARDS.	TOTAL		REMARKS.
			LINEAL FEET.	CUBIC YARDS.	
JUNE 1ST. TO JUNE 3RD.	9.0	162.3	9.0	162.3	
JUNE 3RD. TO JUNE 29TH.	86.0	1550.0	95.0	1712.9	
JUNE 29TH. TO JULY 31ST.	90.0	1622.7	185.0	3335.6	
JULY 31ST TO SEPT 2ND.	107.0	1929.2	292.0	5264.8	
SEPT 2ND. TO SEPT 30TH.	98.0	1766.9	390.0	7031.7	
SEPT 30TH TO NOV. 1ST.	125.5	2262.7	515.5	9294.4	
NOV. 1ST. TO NOV 16TH.	59.0	1063.8	574.5	10358.2	

MAXIMUM MONTHLY PROGRESS, OCTOBER = 125.5 LIN. FT.
AVERAGE " " 104.45 " "

AVERAGE CUBIC YARDS PER LINEAL FOOT OF HEADING AND ENLARGEMENT = 10.2

AVERAGE CUBIC YARDS PER LINEAL FOOT OF BENCH = 18.03.

No. 3.

PROGRESS TABLE.

TOP MILL TUNNEL.

NORTH HEADING.

DATE. 1889.	Lineal Feet.	Cubic Yards.	Total. Lineal Feet.	Total. Cubic Yards.	Side Enlargement. Lineal Feet	Side Enlargement. Cubic Yards.	REMARKS.
March 22nd. To March 30th.	20.0	100.0	20.0	100.0			Heading 10' x 13.5'
March 30th. To May 6th.	82.6	429.5	102.6	529.5	102.6	517.0	" 10 x 13.5'
May 6th. To June 3rd.	37.5	195.0	140.1	724.5	37.5	187.5	Force Variable.
June 3rd. To June 29th.	68.0	693.6	208.1	1418.1			" "
June 29th. To July 31st.	56.0	571.0	264.1	1989.1			" "
July 31st. To Sept 2nd.	102.0	1040.4	366.1	3029.5			Full Shifts and Constant Force
Sept. 2nd. To Sept 30th.	80.0	816.0	446.1	3845.5			
Sept. 30th. To Oct 31st.	76.0	775.2	522.1	4620.7			Small Hole Through Oct. 25th 1-30 P.M.
Oct. 31st. To Nov. 6th.	34.4	350.9	556.5	4971.6			

MAXIMUM MONTHLY PROGRESS AUGUST = 102.0 LIN. FT.

AVERAGE " " 74.2 " "

MAXIMUM WEEKLY " OCT. 7th. TO 14th 25.0 " "

AVERAGE CUBIC YARDS PER LIN. FT. OF HEADING AND ENLARGEMENT = 10.2.

NORTH BENCH.

DATE. 1889.	Lineal Feet.	Cubic Yards.	Total. Lineal Feet.	Total. Cubic Yards.	REMARKS.
May 15th. To June 3rd.	45.0	811.3	45.0	811.3	
June 3rd. To June 29th.	81.0	1460.5	126.0	2271.8	
June 29th. To July 30th.	86.0	1550.6	212.0	3822.4	
July 30th. To Sept. 2nd.	81.0	1460.5	293.0	5282.9	
Sept 2nd. To Sept 30th.	89.0	1604.7	382.0	6887.6	
Sept. 30th. To Oct. 31st.	116.0	2091.5	498.0	8979.1	
Oct 31st. To Nov. 16th.	58.5	1054.7	556.5	10033.8	

MAXIMUM MONTHLY PROGRESS OCTOBER. 116.0 LIN. FT.

AVERAGE " " 92.75 " "

AVERAGE CUBIC YARDS PER LINEAL FOOT OF BENCH = 18.03.

Timbering began	Apr. 23, 1889	
" finished	Dec. 3, 1889	
Cubic-yards excavation in Heading and Bench		17,482
N. W. Approach Cutting began	Mar. 27, 1889	
Cubic-yards excavation		1,831
N. W. Heading began	April 8, 1889	
" " finished	Nov. 7, 1889	
" Bench began	June 1, 1889	
" " finished	Nov. 17, 1889	
Timbering began	May 9, 1889	
" finished	Nov. 7, 1889	
Cubic-yards excavation in Heading and Bench		16,478

TOP MILL TUNNEL.

South Approach Cutting began	April 23, 1889	
Cubic-yards Excavation		10,951
North Approach Cutting began	Dec. 21, 1888	
" " " finished	March 21, 1889	
Cubic-yards Excavation		7,508
North Heading began	March 22, 1889	
" " finished	Nov. 6, 1889	
" Bench began	May 15, 1889	
" " finished	Nov. 16, 1889	
Timbering began	April 25, 1889	
" finished	Nov. 16, 1889	
Cubic-yards Excavation in Heading and Bench		15,710
Total Cubic-yards Excavation in Approaches		25,751
" " " " Tunnels		49,670

APPROXIMATE COST OF LABOR.

Labor cost in excavating Heading and side enlargements, per lin. foot	$ 22.79
Cost per Cubic-yard	2.235
Labor Cost of erecting and packing Arch timbers, per lin. foot	3.19
Cost per 1000 ft. B. M	7.80
Labor cost in excavating Bench per lin. foot	20 95
Cost per Cubic-yard	1.105
Labor Cost of erecting plumb-posts and side lagging and packing same per lin. foot	2.333
Cost per 1000 ft. B. M	4.27
Labor cost of excavating Tunnel per cubic-yard	1.55

APPROXIMATE COST OF LABOR PER LINEAL FOOT OF TUNNEL.

Labor-excavating	$43.74	
Hauling and Dumping	5.65	
Timbering—Labor	4.19	
Framing Timber	.77	
Blacksmithing	1.00	
Track repairs	.21	
Electric Lighting—(Labor)	.88	
Superintendence and accounts	2.00	
Total cost of Labor per lin. foot	$58.44	
" " " " cubic-yard	2.06	6–10

The above does not take into account the cost of the timber, explosives, oil used for illuminating and lubricating, wear of tools, cars, &c., fuel used in smithing or in Electric Lighting plant.

The amount of dynamite used was very nearly 1 pound per cubic-yard of Tunnel excavation.

FORCE, WAGES AND ACCIDENTS.

The work was prosecuted day and night in two ten hour shifts, except on Sunday and Sunday nights, when no work was done except moving of tracks and putting in switches and extra timbering.

The class of men employed was made up of the following, The majority of the foremen were Irish and remainder Austrians. The heading men were composed of about two-thirds Negroes, the remainder being Austrians. The remaining labor was made up of Italians, Hungarians, Irish and a few Americans.

The best heading men were the Negroes, who seem to be perfectly at home with the hammer and drill. Their chief characteristic was to strike in time. Their accompaniment of weird and monotonous chant (sometimes pitched in a minor key), to the sound of clinking steel made an impression upon a sensitive ear not soon to be forgotten.

Average number of men employed was 350.

The average scale of wages was as follows:

HEADING GANGS.			
1 Foreman	$100.00	per	month.
14 Drillers	1.75	"	day.
10 Muckers	1.50	"	"
1 Nipper	1 25	"	"
BENCH GANGS.			
1 Foreman	75.00	"	month.
6 Drillers	1.75	"	day.
16 Muckers	1.50	"	"
2 Men (lagging)	1.50	"	"
1 Nipper	1.25	"	"
2 Drivers	1.50	"	"
3 Dumps-men	1.50	"	"
2 Mules or horses			
MISCELLANEOUS.			
1 Carpenter	2.50	"	"
4 Sawyers	1.75	"	"
1 Trackman	2.50	"	"
3 Blacksmiths	3.00	"	"
1 Walking-Boss	100.00	"	month.
1 Time-keeper	60.00	"	"
1 Engineer and Fireman	65.00	"	"
1 Electrician	65.00	"	"

ACCIDENTS.

Much care was taken to protect the workmen from accidents. Those that did occur were from the carelessness of the injured men themselves. There were but three serious accidents and none that proved fatal.

LIGHT, EXPLOSIVES AND BLASTING.

At night 2,000 candle power arc lights were used in headings on benches and dumps. The light was furnished by a Thompson-Houston 20 light dynamo driven by a 25 H. P. engine.

The deep shadows cast by the electric lights made it necessary to use small miner's lamps besides.

During the day gasoline and miner's lamps were used. "Miner's Oil," a brand composed largely of cotton seed, was used in small lamps. It gave a good light but with considerable smoke.

The American Forcite Mfg. Co.'s No. 3 Forcite, 40 per cent. N. G., was the explosive principally used throughout the work. Its qualities are: safety in handling as it is not very sensitive to percussion; Quintuple free detonaters are required to explode it; its comparative freedom from any noxious fumes; its comparative high intensity, are advantages which should be appreciated. Electric plunge batteries were used to explode all charges except an occasional block hole.

ENGINEERING.

During October, 1888, a system of triangulation was conducted which covered the entire territory under location from the Cleveland & Pittsburg Railroad track in Martins Ferry, Ohio, to the Peninsula on Wheeling Creek. (Fig. 18.)

The Base Line "B. C." was 2,140 ft. long, and was carefully measured along the C. & P. R. R. tracks and checked by a 100 ft. Chesterman steel tape. A secondary base line "J. K." was established on the Peninsula, a mile distant, and not visible from the base line in Martins Ferry.

The angles were the mean of from four to six readings; the instrument used was a 6¼ plate, Buff & Berger, graduated to 30 seconds.

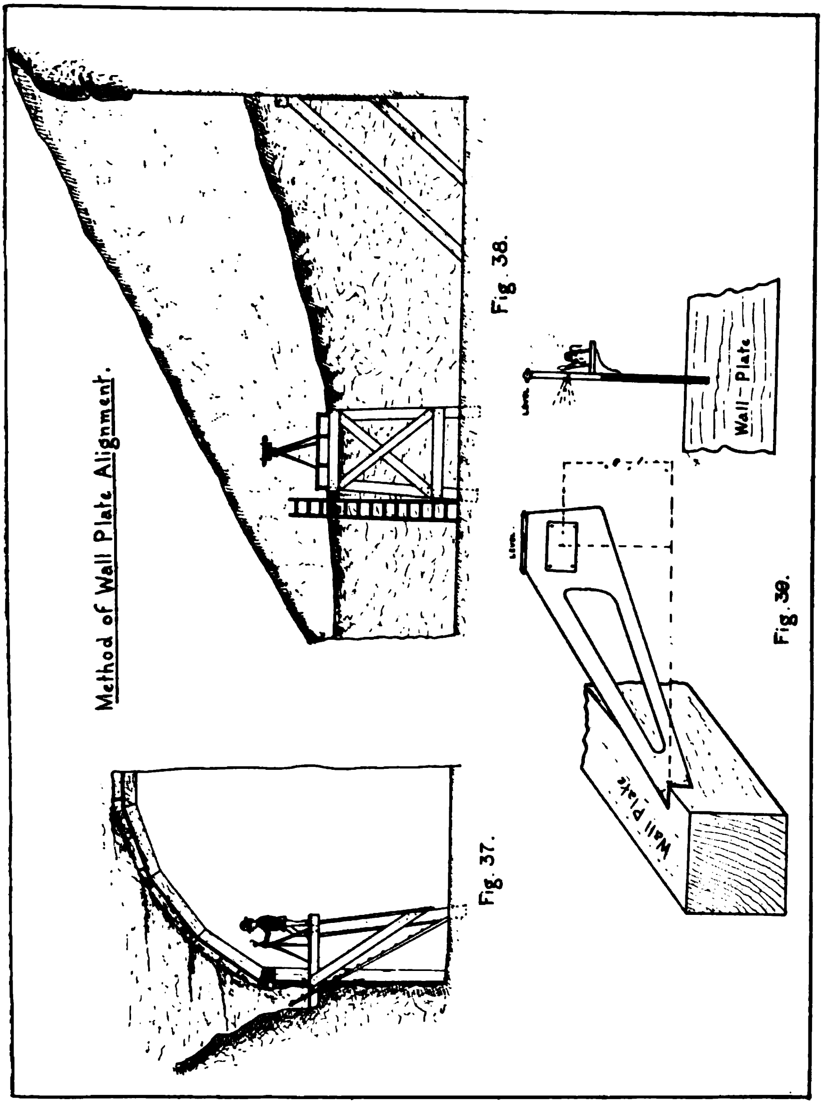
COMPARISON OF RESULTS.

Base line "B. C." primary measured	2,140 ft.	
" " "J. K." secondary "	695.03	
" " " calculated	694.84	
Difference	-.19	
Calculated angle. Intersection "M."		40° 44′ 39″
Measured " "		40° 44′ 35″
Difference		-04″
Calculated distance "M to P"	1,105.3	
Measured " "M to P" (very difficult)	1,105.7	
Difference	+.4	
Calculated angle of intersection at "P"		27° 34′ 20″
Measured " " " " "		27° 34′ 15″
Difference		-05″
Calculated distance "Y to P"	1,437.43	
Measured " "Y to P"	1,437.34	
Difference	-.09	

METHODS OF ALIGNING WALL PLATES.

In setting the wall plates much care was taken to have them placed in their true position, that is, relative to line and grade and square with one another.

The usual way of accomplishing this, and which was at first used, was as follows: The center line was established on the floor of the heading at the farther end of the wall plates, then the levels were carried in from a permanent bench mark near the



Portal; a turning point was taken on the top of the scaffold car by means of a steel tape. The level was then set up in the heading and the proper elevations of the farther end of the wall plates

given, the ends of the wall plates being raised or lowered until the desired result was obtained. Measurements were also taken from the center line previously established and the wall plates

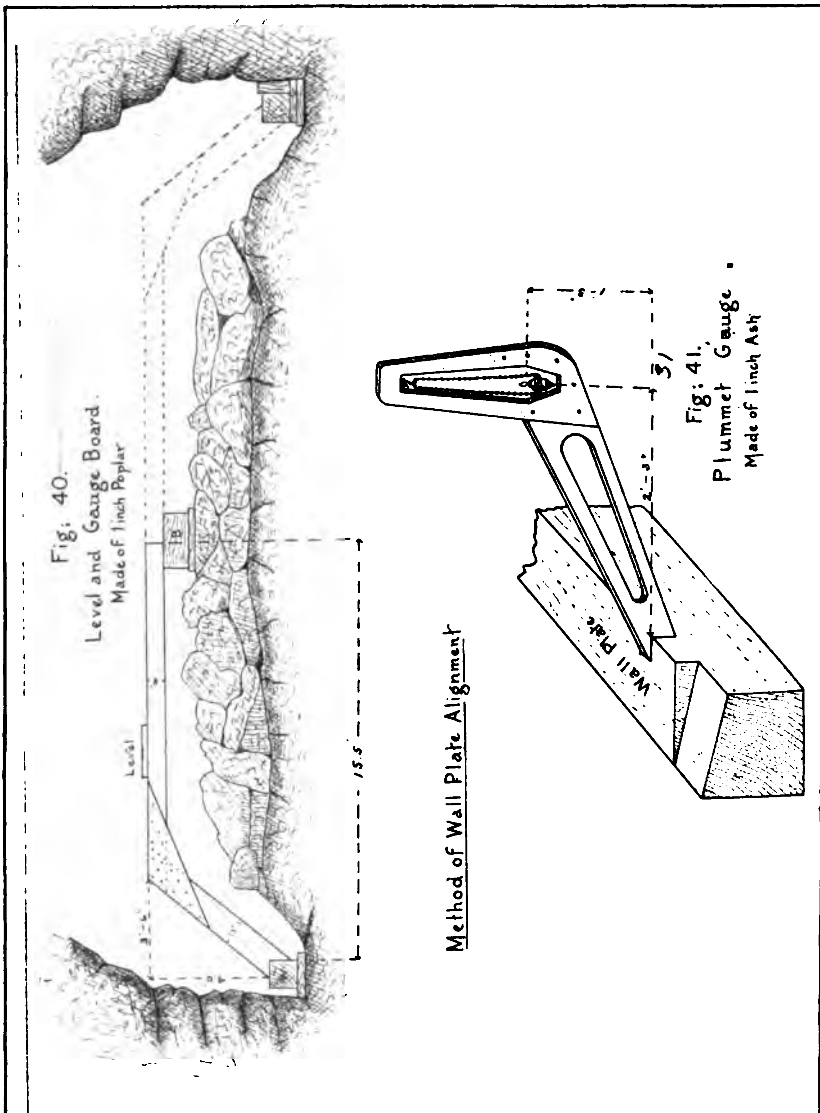


Fig: 40. Level and Gauge Board. Made of 1 inch Poplar.

Fig: 41. Plummet Gauge. Made of 1 inch Ash.

Method of Wall Plate Alignment

set at the proper distance from the center. When in their true position they were blocked between the back side of the plate and the wall to prevent their being displaced. This method re-

quired considerable time and interrupted the work. After the work was somewhat advanced, a method of aligning the wall plates was devised by the engineer in charge, Mr. H. F. Dunham.

Mr. Dunham read a paper describing this method before the American Society of Engineers May 4, 1892.

This method was as follows: Near the portals at one side of the roadbed, stands made of heavy oak timbers were erected and drift bolted together and into the rock and properly braced. (See Figs. 37-38.)

On top of the stands was laid a platform about 4 by 6 feet. It was so arranged that the top of the platform should be about ten feet above grade. A ladder was placed at one side leading to the platform on which was to be placed a "Y" Level. At the points where the shoes of the tripod were to rest ¼ inch iron plates, with a ¾ inch hole in the center, were spiked to the floor, care being taken to have the plates come over the floor joists.

The plates were to prevent any wearing and consequently settlement of the instrument. One of the legs of the tripod was marked corresponding to a particular hole. The instrument being in place was then leveled up and its true position relative to the line and grade of the wall plates (produced to that point) was ascertained. Care was taken that the H. I. should be a little more than one foot above the grade of the wall plate, and that the center of the instrument should be two feet or a little more from the inner edge of the wall plate line. At the S. E. end of Mount Wood Tunnel, a target made of tin, painted white on which were black lines intersecting like the letter X, was placed on an 8''×8'' oak post set 5 feet in the ground and well braced, about 1,000 feet from the instrument on the Peninsula, the position of the lines intersecting on the target was placed in the same relative position to the wall plate grade and line (produced to this point) as the cross wires of the instrument were to the wall plate line and grade at that point.

When line and grade were to be given, an assistant was sent into the heading with instructions to hold a bracket in which was suspended an 16 oz. plummet lamp (See Fig. 41) on the farther end of the wall plate. It was necessary that this bracket should be held square with the wall plate and should be lowered or elevated until the point of the plummet was over a small pin placed in the bottom of the slot the plummet hung in. When everything was in readiness, the instrument was leveled transversely, the clips were unfastened, and the telescope directed towards the target; the instrument was then clamped and by the means of the two leveling screws under the bar and the tangent screw, the cross wires were brought to intersect the target.

The telescope was then lifted gently from the Y's and reversed. When the wall plate is moved until the intersection of the cross wires cover the flame of the plummet lamp, then the three are in line and the wall plate is correctly placed for both line and grade.

When this had been accomplished, to set the opposite wall plates a gauge board and spirit level were used. (See Fig. 40.)

The length of the gauge board was equal to one-half the distance between the wall plates. When the gauge board was leveled on to the blocking in the center, the point was marked and the board swung around to the wall plate to be set. This was a very simple operation and required but a few moments. Fig. 39 is a suggested improvement over the bracket. For by using a bubble instead of the plummet and a common miner's lamp set on the shelf so that the flame will illuminate the bubble and shine through a small diamond shaped hole in the metal plate. It is much easier for the assistant to see when it is in the proper position.

At the northeast end of the Mount Wood Tunnel in Jonathan's Ravine and also at the North end of Top Mill Tunnel, sufficient distance back of the stands could not be had for targets, so that tested points in that part of the tunnel already completed were used as foresights. Pieces were spiked to the plumb posts and boards laid on them to form a platform for the assistant to stand on while giving the foresight with the same bracket used in the heading.

This method worked very well and was much quicker and hence more economical than the usual method.

When everything was ready, from 10 to 15 minutes was all the time required to set the wall plates and the workmen were not stopped, while by the other way, the work was more or less interrupted and it required usually an hour's time to do it.

A bracket and gauge board was kept at each heading. After the Mount Wood Tunnel was completed a test was made by having the instrument at the stand near the southeast portal, with backsight on target on Peninsula. A target was temporarily placed in Jonathan's Ravine from the stand at that point and the line produced from the Peninsula varied but little from that target. Proving the accuracy of the method.

PERSONNEL.

It is but proper that some mention be made of the intelligences that planned, directed and executed this work.

The Chief Engineer was the late Job. Abbott, M. A. S. C. E., an engineer of great ability and a man of becoming modesty.

He was ably assisted by Mr. H. F. Dunham, M. A. S. C. E., of New York.

The Contractors who carried the work to successful completion were Paige, Carey & Co., of New York, Mr. Frank Moran being their Superintendent.

I wish to thank the gentlemen who have aided in making such an excellent presentation of the illustrations accompanying this paper.

Fig. 42. Carboniferous fossils found on Jonathan's Ravine.

FIG. 43. Southeast portal, Mount Wood Tunnel. View from "Peninsula." Showing temporary trestle over Wheeling Creek, May 12, 1889.

FIG. 44. Southeast portal, Mount Wood Tunnel, showing No. 8 coal vein over portal, May 12, 1889.

FIG. 45. Northwest portal, Mount Wood Tunnel, in Jonathan's Ravine, May 28, 1889.

Fig. 46. South approach cut (in Jonathan's Ravine) to Top Mill Tunnel, May 28, 1889.

FIG. 47. North portal, Top Mill Tunnel, May 23, 1889.

FIG. 48. Southeast portal, Mount Wood Tunnel, July 3, 1889.

FIG. 49. Southeast portal, Mount Wood Tunnel, showing timber lining, July 3, 1889.

FIG. 50. Northwest Mount Wood Tunnel—124x40—October 9, 1889.

FIG. 51. 'Northwest heading, Mount Wood Tunnel—123x70—October 30, 1889.

FIG. 52. Northwest Bench, Mount Wood Tunnel—124x30—October 30, 1889.

FIG. 53. Approach cut and south portal of Top Mill Tunnel from Jonathan's Run, December 27, 1889.

FIG. 54. North portal, Top Mill Tunnel, showing temporary track, December 27, 1889.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

POWER TRANSMISSION FROM NIAGARA FALLS.

BY ORRIN E. DUNLAP.

(*Cassier's Magazine, January, 1897, p. 197.*)

At midnight on November 14, connection was made at the main power house of the Niagara Falls Power Company at Niagara Falls, between the famous Niagara generators and the transformers in the nearby transformer house, which, in turn, were connected with the City of Buffalo power transmission line, and at the same instant the electric power of Niagara was, for the first time, sent out beyond the confines of its birthplace and on direct to Buffalo, a distance of twenty odd miles. The power is used on the lines of the Buffalo Street Railway Company.

The three-phase system of transmission is used, and as the line is not quite direct and as there are three cables, their combined length is about seventy-eight miles.

It is recognized that this power line is destined to eclipse all other, owing to the market available for the power, and because the amount of power developed, and to be developed, will be an incentive to add to its capacity. The Niagara Falls Power Company are fortunate in more ways than one. Their plant has a practically unlimited water supply by which many thousands of horse-power can be developed, and in addition to this their power house is situated in a section of country where there is great demand for power. The possibility of such wonderful power development is one factor of importance, while the extended demand for their product is another which gives encouragement to the capital invested to accomplish things far beyond what man has ever before attempted.

In the construction of the Niagara-Buffalo line the power company have been governed by their rule to build the best possible work, and for this reason the line is a good example of strength and careful engineering. In no part has any known weakness been allowed to creep in, but in all the contracts the demand has been for perfect material and perfect construction.

The electrical equipment necessary for the transmission of power to Buffalo was furnished by the General Electric Company of New York, and comprises, among other things, three air blast transformers with blower motor, switchboards, etc. Any two of these transformers can be used to transform 2,500 horse-power in quarter-phase currents at 2,200 volts to three-phase currents at either 11,000 or 22,000 volts. The third transformer will be

held in reserve, all being interchangeable. The primary and secondary connections of these transformers are each led to a switchboard. The low-tension board is fitted with switches and fuses; the high-tension board is fitted with switches, fuses and indicators. Lightning arrestors are also provided where the conductors leave the transformer house.

The transformers are supported on an iron frame work, their bases being eight feet below the floor of the transformer house, and the space below them being practically an air-tight enclosure. It is through this enclosure that all connections to the transformers are made, there being ample room for walking about. The connections to the transformers themselves are made so that they can be easily detached, and in case it is found necessary or desirable to substitute the extra transformer for one of those in use, the existing connections can easily be broken and the transformer removed with the crane in the building, and the extra transformer set in its place.

A large blower, which stands in one corner of the room, and is driven by a five horse-power electric motor, delivers air to the enclosure below the transformers and this air passes upward through the spaces between the coils. The amount of air delivered is controlled by valves.

The arrangement of coils is such that exceedingly strong insulation will have to be punctured before connection can be made between different coils. At the same time, the air spaces are so placed that the air is brought in close contact with each coil and gives an excellent cooling effect. Naturally, this method of cooling tends to increase the size of the transformers, but it has the advantage of making them clean and accessible and more convenient to handle.

The Cataract Power and Conduit Company, of Buffalo, was incorporated in July, 1896, for the purpose of becoming the distributing agents of Niagara power in the city of Buffalo. It has George Urban, Jr., as president; Charles R. Huntly, as vice-president and general manager; William B. Rankine as secretary and treasurer, while E. D. Adams, Francis Lynde Stetson, D. Ogden Mills, John Jacob Astor, E. A. Wickes and Daniel O'Day are on the Board of Directors.

Under the contract made with this company by the General Electric Company, of New York, four 360 horse-power transformers were furnished for reducing the current as it comes from the transmission line to a voltage suitable for connection to 500-volt rotary converters. A special building was erected in connection with the Buffalo Street Railway Company's plant for these transformers at the Buffalo end of the line. The method of cooling and the general construction is very similar to that used in the large transformers at Niagara Falls. This building is also provided with lightning arresters and a switchboard.

It was with the Buffalo Street Railway Company that the General

Electric Company made still another contract, and to them they furnished two 500 horse-power rotary converters with switchboards and accompanying instruments. These converters will supply current to the lines of the Buffalo Street Railway Company in parallel with the generators now in their power house. The machines have six poles and operate at a speed of 500 revolutions per minute. They are so installed as to make it possible to start them either from the alternating current, or by direct current from the lines to which they are connected.

It is probable that no pole line was ever better constructed than that from Niagara Falls to Buffalo. Work was commenced on August 14, 1896, and on November 14 the line was turned over to the Cataract Construction Company, practically finished. In this period the poles had been obtained, set, painted, and the insulators placed and cables strung. In height the poles vary from thirty-five to sixty-five feet. They are all of white cedar and are shaved. They are set from sixty to seventy-five feet apart, the distance being varied in order to overcome any possible vibrations of the spans during the high winds which frequently prevail in that locality. All the poles are painted with two coats of pure white lead and boiled linseed oil.

In turning sharp angles, as at corners, six poles are used instead of three, and these are braced by poles extending from the bottom of the opposite poles. Where the double-pole construction is employed, double cross-arms are also used. These double cross-arms are 24 feet long and measure 6×12 inches.

All single poles have three cross-arms, the two upper arms being used for power cables, and the lower arm to carry a telephone wire. The upper cross-arms are of the same size, 12 feet long by $4\frac{3}{4} \times 5\frac{3}{4}$ inches, and are of yellow pine. They are supported by solid braces of 2×2 inch angle iron. The lower cross-arms are 6 feet long by $3\frac{1}{4} \times 4\frac{1}{4}$ inches, and are supported by $1\frac{1}{2} \times \frac{1}{4}$ inch angle iron braces.

All the cross-arms are staggered, and the gains are painted before the arms are set. The upper cross-arms carry pins on which a line of galvanized iron fence wire is strung as a lightning protector, and another line of this wire is strung along the apex of the poles for a similar purpose. These lightning protectors are grounded at frequent intervals along the pole line. The pin holes in the cross-arms have a depth of four inches, and all have drainage holes. The pins were not nailed in position until after the insulators were placed.

Two styles of insulators are in use on the line—one made by the General Electric Company, and one by the Imperial Porcelain Works, of Trenton, N. J. The latter insulator is known as the "Niagara type." In shape it is oval, and it has a projecting rim around the bottom to aid in throwing off water. This insulator is nearly as large as a Derby hat, and of goodly weight. The other insulator is round in shape.

In the transmission, transposition is effected every five miles, and at these points two poles five feet higher than the adjoining poles are placed. The cable strung on the pole line is one of bare copper having nineteen strands.

About seventy-five miles of this are used in the three lines, forming one three-phase system. The cable was shipped to the work on large reels, each carrying about a half-mile length. These reels were loaded on to a reel cart and horses drew this heavy load along the line as the cable was paid out, a simple movement of a lever bringing the cable up taut on the arms.

At the Buffalo end of the line, for about 4,200 feet, the cables are laid in a conduit made of twelve vitrified tile ducts, each of which has a diameter of three inches in the clear. These tiles are laid in concrete with four inches as the minimum protection on all sides. The trench to accommodate them was excavated to a depth of about forty inches, but this was governed by the locality. The average depth of soil over the conduit is eighteen inches. The conduit is laid along the Erie Canal bank, but in no place does it approach the edge nearer than fourteen feet, holding close to the sixteen-foot mark on the inside line. About sixteen manholes, octagonal in shape, are located along the conduit. They are surrounded by a brick wall twelve inches thick, the bottom being formed by six inches of concrete and one layer of brick.

The terminal of the pole line at Buffalo is a brick house, twenty-two feet high, and its interior dimensions are 16×9 feet. A short tunnel leads from the last manhole in the conduit to the house. The cable laid in the conduit aggregates 12,345 feet in length for the three circuits. The rubber insulation is 9-32 inch thick and is covered with rubber tape. The lead sheath is 7-64 inch thick. Samples of the cable have withstood 40,000 volts successfully.

The cable, after entering the terminal house through the short tunnel above referred to, is carried up inside on a trestle and the ends are sealed. A rubber-insulated cable without lead is carried out to the first pole, and there connected with the bare copper cable of the pole line. The terminal house is fitted with lightning protectors.

It is already apparent that the transmission line is to be an important factor in building up the section of country between Niagara Falls and Buffalo. For about eighteen miles of the distance to Buffalo the transmission line runs through private property, the right of way over which was purchased by the Niagara Falls Power Company. This strip of land is thirty feet wide, and in the construction of this first line the poles have been set to the east side of the center, the outside boundary of the strip being one foot beyond the outside end of the large cross arms. This method was adopted so that another line can be constructed along the west side of the strip when the occasion demands. The ownership of the land also makes it possible for the owners of the line

to pass along it without trespass, and affords them excellent facilities for guarding it. The poles are set at a depth of from six to eight feet, and where soft soil was met they were set in concrete.

Power was first transmitted over the line early on the morning of Monday, November 16. In the power house at Niagara Falls, Mr. William B. Rankine, secretary of the Niagara Falls Power Company, threw the feeder switch and this let the current pass from the house to the transformer room adjoining. Beside Mr. Rankine, when he did this memorable act, stood Paul M. Lincoln, electrical superintendent of the power plant, and Mr. William A. Brackenridge, resident engineer of the Cataract Construction Company, under whose personal supervision the transmission line had been constructed and the electrical equipment installed.

Over in the transformer house was Mr. I. R. Edmonds, of the General Electric Company, who threw the low-tension and high-tension switches of the installation there, letting the current pass into and through the transformers and out over the line to Buffalo, where it was successfully received, and its arrival heralded by the booming of cannon, even though the hour was midnight.

At the Buffalo end of the line there was a notable gathering of prominent men. Mr. W. L. R. Emmet, of the General Electric Company, was in charge of the apparatus on behalf of his company. The mayor of Buffalo, leading editors and officers of the Cataract Power and Conduit Company and the Buffalo Street Railway Company were also there to welcome the coming of Niagara energy.

The product of the big generators at the Falls is now being daily transmitted to Buffalo at a voltage of 11,000, and 1,000 horse-power is being used in that city for the propulsion of trolley cars.

AMERICAN AND ENGLISH METHODS OF MANUFACTURING STEEL PLATES.

By Jeremiah Head, M. Inst. C. E.

(Proceedings Institute Civil Engineers. Vol. cxxvi, p. 132.)

SUMMARY OF CONCLUSIONS.

The author is of opinion that the following conclusions may be drawn from this comparison between American and English methods of manufacturing steel plates, viz:—

(1.) There being no extensive demand for ship and marine boiler plates in America such as obtains in Great Britain, several other important uses have been developed.

(2.) American practice supports the view that equally good steel may be made by any of the four modern processes if equal care be taken; and that basic linings to open-hearth fur-

naces are advantageous, even where high-class pig-iron is plentiful.

(3.) It also shows that, as regards the quality of product and economy of production, the intermediate process of cogging is by no means indispensable.

(4.) By the extensive adoption of labor-saving appliances (more especially electric motors), and by keeping the work in progress almost continually on wheels or power-driven rollers, labor is minimized in America to an extent seldom reached in Great Britain.

(5.) The American standard plate-mill is, in the author's opinion, superior to that usual in this country, because it admits of a quicker reduction in the thickness of the ingots or blooms submitted to it, a more economical engine and less intermediate gearing. The single stand of three chilled rolls, worked always wet, is simpler and better than two stands of rolls, with one traversing and two fixed roller frames.

(6.) The American plan of cooling the plates on live rollers, and inspecting and marking them in transit, appears to be a decided improvement on English practice, and so also does the use of castor-rollers in front of the shears.

(7.) The best performance in the United States does not differ greatly from the best performance in this country, as shown in the table at page 149. Steel in both cases compares very favorably with iron-plate making.

(8.) The modern English plate-shears, actuated by a pair of cylinders without a fly-wheel, is an improvement on the existing American practice.

THE UNDERPINNING OF HEAVY BUILDINGS.

By Jules Breuchaud, Assoc. Am. Soc. C. E.

(*Proceedings of the American Society of Civil Engineers. Vol. xxii, p. 630.*)

As compared with other work of the same class heretofore executed in that vicinity, the problem of supporting the adjacent buildings was unusually difficult in this case, as the plans provided for the placing of the rectangular caissons almost contiguous with one another and exactly on the boundary lines of the lot, an arrangement which had not been previously attempted.

The attention of the author had already been called to the fact that considering the increasing height of the buildings which are now being erected for business purposes on comparatively small areas, a limit would soon be reached beyond which it would not be economical, or even practicable or safe, to use timber supports, even of such special and ingenious design as have been recently adopted for such purposes.

The peculiar conditions under which the work had to be done in this case led to the conclusion that it would be desirable to resort to such devices as would leave the limited space at hand entirely free from interference, and open at all times for the free handling of the pneumatic, hoisting and other plants, for the movement of bulky caissons and for placing them strictly on the boundary lines of the lot. This latter result was literally accomplished, the rivets of the steel caissons in their downward progress leaving, in many instances, their marks on the brick surfaces of the adjacent walls.

The method followed consisted of placing vertical iron supports directly under the walls to be supported in the following manner:

After determining the number of supports necessary for supporting the superincumbent weight, a vertical slit was cut into the wall from the bottom upward, for a distance depending on local circumstances, generally from 10 feet to 12 feet, the slit being of such a width as would amply accommodate the pipe which had been determined to be sufficient in diameter for each case. On the top of that slit a short transverse horizontal cut was made, in which one or more iron I-beams were built. The iron column or pipe which was to support the wall being divided into pieces of proper length, which could be either screwed together or united by means of bolted interior flanges, the first length was placed on end on the ground in the slit of the wall. Blocking being then placed on the top of the pipe, a jack was inserted between the pipe and the short I-beams built on the top of the slit, and either by simple pressure or with the aid of a water-jet, the first pipe was pushed down, by alternate jacking and blocking, to its full length. Next, a second piece of pipe was fastened on top of the first, and the sinking operation was resumed until another pipe could be added to the second, and so on until the pipe had reached bed-rock, or such other support as was sufficient.

The top of the highest pipe was left at about the level of the bottom of the wall, in which another set of short horizontal I-beams was built reposing on the top of the pipe. Vertical beams or columns were then firmly wedged between the two sets of horizontal I-beams, and the slit in the wall was filled up with brickwork. These vertical beams were used to avoid the compression which would otherwise occur in the fresh masonry built in the vertical slit.

Only one or two supporting pipes were, obviously, driven at a time, in order to avoid excessive concentration of weight on the other parts of the foundation while the pipes were being sunk.

THE USE OF CONCRETE FOR BRIDGE FOUNDATIONS.

By J. DeGurse, C. E., O. L. S.

(*Proceedings of the Association of Ontario Land Surveyors, 11th Annual Meeting, 1896.*)

During the summer of 1895 I was requested to prepare plans and specifications for three steel viaduct bridges on the London and Port Stanley Railway.

No. 1, over Kettle Creek, consisted of fifteen plate girder spans, each thirty-six feet in length, excepting the two end spans, which were twenty-eight feet in length, and one truss span of eighty-five feet over the Creek. The girders rested on columns braced together transversely to form bents, each pair of which was braced together to form towers, the bents varying in height from sixteen to sixty-two feet.

No 2 was over Mill Creek, south of St. Thomas, similar to No. 1, but had no truss span.

No. 3 was over Zavitt's Pond, near Port Stanley, and has a total length of 228 feet.

The sub-structure for each of these bridges consisted of a masonry abutment at either end, and a pier or pedestal under each column. The abutments were composed of stone masonry to the depth of ten feet beneath the bridge seat, resting on a bed of concrete of sufficient depth to reach a hard clay foundation.

Each of the pedestals was composed of concrete surmounted by a stone cap four feet by eighteen inches in depth, and pierced with two anchor bolts one and one-eighth inches in diameter, and four to five feet long.

I should have preferred to have dispensed with the stone cap, but had to give way somewhat to prevailing prejudice. The concrete pedestals varied in depth from five to nine and one-half feet, and were in the shape of a frustrum of a pyramid with a batter of one in six, the surface under the stone cap being three feet nine inches by three feet nine in all cases, except those on either side of Kettle Creek, which were larger, likewise the stone cap surmounting them.

The pedestals were made as follows:

The ground was excavated to the required depth to reach a hard clay or gravel foundation, when a strong box having the required batter and proper dimensions was lowered into the excavation, securely braced and properly centered. The concrete after being mixed was shoveled into the box and rammed.

As soon as sufficiently set, the box was removed, after which the concrete was kept wet for about a week, and until no further damage was anticipated from the outer layer drying too quickly

and robbing the mortar of moisture which is so essential to crystallization. After which a mortar bed, composed of one part of cement to two parts of sharp sand, was placed, of sufficient depth to receive the stone cap, and bring it to the proper elevation.

The concrete used in the pedestals and beneath the stone abutments was composed of one part Portland cement, two parts of sand and three parts of broken stone. The cement specified for the work was star brand Napanee Portland, but on account of the great demand for this brand, the contractors, except in the case of the latter bridge, were unable to secure this cement, and imported brands were used.

The specifications required that there should not be more than 5 per cent residue on a sieve of 1,000, and that the tensile strength at the end of seven days, one day being in air should be 350 lbs. per sq. inch. That the sand used should be clean, sharp, and on the coarse side, free from loam, and of a silicious nature. That the stone should be good hard limestone, broken so as to pass through a two inch ring, and just before being used, sprinkled with sufficient water to remove all dust and thoroughly wet the entire surface.

The mode of preparing the concrete was as follows:

Two barrels full of sand were spread evenly over a platform twelve feet by twelve feet, on this one barrel of cement was evenly spread, when the two were turned over at least three or four times while dry, enough water was then added to form a stiff paste; after being levelled the three barrels of broken stone were evenly spread over it, and repeatedly turned over until the ingredients were thoroughly incorporated; it was then put in place as quickly as possible and evenly and sufficiently rammed.

In Bridge No. 3 six of the pedestals were found over quicksand foundation, and with these I proceeded as follows:

I procured nine piles of sufficient length and spaced as per annexed sketch for each pedestal, had them driven to a refusal with a 2,000 pound hammer, and sawed off two feet below the surface of the ground. Instead of following the more general practice of capping and flooring, I had the soil excavated from two to three feet below the top of the piles, and had the concrete rammed between, around, and on top of the piles until sufficient height had been obtained to receive the cap stone.

By this method the bearing power of the soil between the piles was utilized, as well as the bearing power of the piles themselves, and the whole formed a monolothic mass which cannot fail in part.

With reference to the durability and resistance of concrete to abrasion, I may refer you to a paper by C. D. Purdon, Esq., A. M., Soc. C. E., in *Engineering News*, Vol. 19, page 443, where the writer, after referring to the mode in which the concrete piers were built, adds:

"On May 7th, I had an opportunity of inspecting them after a most extraordinary flood in the river, caused by a water spout, in which flood the river rose one and four-tenths feet above the highest water known, the current being estimated at from eight to nine miles per hour with large quantities of drift running. Among the drift were cotton wood trees two feet to three feet in diameter, many of which I am informed broke on the piers from the force of the current. No damage whatever was done to the piers, and no greater marks left by the drift than could be made by a stick held in the hand and dragged across the surface.

"It was the opinion of the Bridge Inspectors of the St. Louis and San Francisco R. R., who watched the bridge during the flood, and who were men of considerable experience, that had the piers been built of masonry of such stone as could have been obtained, they would not have been able to withstand the drift and the bridge would have been destroyed."

A UTAH ATTEMPT AT SETTLING CONTESTED WATER-RIGHTS

By W. P. Hardesty, Salt Lake City, Utah, Mem. Am. Soc. Irr. Eng'rs.

(*Transactions American Society Irrigation Engineers. Vol. ii, No. 2, p. 64.*)

The following article is descriptive of an attempt by Utah courts to secure an accurate and scientific measurement of waters that had been decreed to parties in dispute—about the first attempt we believe of this kind in Utah jurisprudence. In the well-known suit of Louis A. Scott Elliott vs. George C. and James Whitmore, which has been in the courts for seven years, regarding rights to water in Grassy Trail Creek, in Emery County, Utah, Hon. J. H. Harris, the referee in the last hearing of the original case, decided that only an absolute measure to apportion the waters in dispute would suffice. The Judge of the Third District Court, in adopting the findings of the referee (May, 1893), appointed the writer as Commissioner to put in a measuring box to give defendants their allowance of 67-150 of a cubic foot per second, the costs, to be equally divided between plaintiff and defendants. The judgment of the court, in ordering the measuring box, states that it "shall be made with two weirs, one wider and one narrower, and so made and graduated as to permit (67-150) sixty-seven one hundred and fiftieths of a cubic foot of water per second to flow into defendants' ditch over the smaller weir and return the overplus of water over and above said sixty-seven one hundred and fiftieths of a cubic foot per second to the bed of the stream by means of the larger weir, which measuring box shall be made incapable of variation by either of the parties hereto, and the weirs shall be

so graduated that there shall be as little variation as convenient in the amount of water flowing over the narrower weir."

It should be here stated that the head-gate to defendants' ditch is some miles above that of the plaintiff's, and the idea was to put the box in defendants' ditch somewhere near the head, so as to measure out their proper allowance and allow the remainder to flow on down the creek.

It is, of course, evident that to deal out a constant supply there must be as little variation as possible in the depth of water over the weir, and to meet this condition there must be either a uniform and exact amount supplied through the head-gate of ditch—of course, impracticable here—or an overflow or excess weir of such length that after the water reaches the proper depth on the measuring weir the excess can have as long a spillway as possible.

* * * *

However, as the sequence will show, the judgments of courts do not always compel respect from the litigants, and so the matter was not to end here at all. The principal one of the defendants, who had never become reconciled to the decree, about two weeks after the box was put in, tore out the ends to let more water go through, and afterwards took it out altogether and restored the ditch to its original condition. He was, of course, promptly arrested and brought to trial for contempt of court.

Punishment was made much lighter on condition that he replace the box within a certain time, which was done, though the box was cut down to about one-third of its former size in the process and also put in another place. The judgment for contempt was appealed from, trials for subsequent contempts were also had with additional appeals—one being carried to the United States Supreme Court—the decree adjudging the water was also appealed from and it seems that the whole proceedings may be reopened, so that altogether this has become one of the most complicated and stubbornly contested cases in the Utah Courts. It is probably but an instance, though, of what may happen in many cases in the arid region where our codes of irrigation laws are very incomplete and unsatisfactory, and in which the questions of priority and use are always causing trouble.

THE VYRNWY MASONRY DAM.

By George Frederick Deacon, M. Inst. C. E.

(*Proceedings of the Institutive Civil Engineers. Vol. cxxvi, p. 28.*)

In 1881 there was probably no high masonry dam in Europe so far water-tight that an English engineer would take credit for its construction. Methods not hitherto practiced were clearly neces-

sary if water-tightness was to be secured. Leakage might not indicate danger, but it was wholly inadmissible in a structure to impound more than 13,000 million gallons of water on a river 200 miles in length and passing such towns as Shrewsbury, Worcester and Gloucester. This and other considerations led to the decision to avoid any division of responsibility by carrying out the impounding works without the intervention of a contractor. Great care, moreover, was taken to avoid the combination of supervision such as a contractor's staff would exercise for the purpose of economy and dispatch, with inspection for the attainment of a high standard of workmanship. All such conflicting functions were kept separate, and the general administration was very much what the separate administrations of the staffs of the engineer and contractor would otherwise have been.

DESIGN.

The cross section of the Vyrnwy dam is shown at Figs. 3, and is dotted in Fig. 4, Plate 4. The design of this dam has been already referred to in the Proceedings of the Institution and the reasons for the departure of its cross section from the form which, upon certain not altogether true hypotheses, mathematical analysis produces, have been discussed. The half-elevation is shown at Fig. 5, Plate 4.

EXCAVATION.

The great width of the base—about 127 feet at the widest part of the intended dam—precluded timbering the sides of the excavation. They were, therefore, sloped at about 1 to 1. The lower levels consisted largely of enormous boulders, and, therefore, with the exception of a single steam-navvy, manual labor was used. The work was carried on night and day, electric light to the extent of about 30,000 candle-power being employed at night.

FOUNDATIONS.

The rock at the bar already described had a dip towards the west. As the glacier moved towards the southeast it had tended to separate the rock at the principal planes of cleavage which were approximately normal to the beds, and masses weighing hundreds of tons, broken from their beds and moved some distance down the valley, or only just detached, were met with. All these, so far as they occupied the site of the intended base, were, of course, removed, leaving the structure indicated at Figs. 3 and 6, and at Fig. 4, Plate 4. The surface rock was met with approximately at the depths indicated by the rock contours, and was almost completely covered with striæ nearly parallel with the axis of the valley precisely as the glacier had left it.

Although no visible springs of water issued from the beds of rock thus exposed, it was by no means certain that, when the reservoir was formed and the head on one side became 144 feet, springs subject to that pressure would not occur. Moreover, a

mere moisture, rapidly evaporated when exposed to the air, might, when sealed down, acquire a pressure from the adjoining hills of far more than that due to the intended level of the lake. The late Mr. T. Hawksley had, from the beginning, laid great stress upon the necessity of rendering any such accumulation of pressure impossible, on the grounds that it might assume considerable importance as one of the forces tending to overturn the dam, and the author agreed with him in thinking it desirable to provide relief drains, which, so far as he is aware, had not been done in connection with any former masonry dam. Accordingly, along the base of each of the more important beds of rock, not within 15 feet of the face of the dam, a drain was formed by the masonry between 6 inches and 9 inches square, and from these drains funnels were carried up in different vertical transverse planes of the dam to above the backwater level. The twenty-seven funnels which occur in a length of only 66 feet of the dam at its deepest part, are shown at Figs. 3. The funnels all issue at the side of a longitudinal tunnel 4 feet 3 inches by 2 feet 6 inches, so that the flow from each, if any, is rendered visible. From this tunnel a cross tunnel, shown in the same figure, serves as an outlet for the water from the rock and as a passage to the main tunnel. At Fig. 6 a section of the rock and masonry surrounding a single drain is shown to an enlarged scale. The quantity of water thus discharged from the foundations has always been very small, and it fluctuates very slightly. For the central length of 214 yards, representing a foundation area of 8,000 square yards, it is only about 2 gallons a minute, including the leakage, if any, through the dam, while the discharge from the end portions is relatively smaller.

THE 5,000 HORSE-POWER TURBINES AT NIAGARA FALLS.

DeVolson Wood.

(*From the Technic University of Michigan Eng. Soc., 1896.*)

The Falls, known the world over as "The Niagara Falls" has, for a long time, been looked at enviously by those desiring water power. At one time a small paper mill a few rods above the crest of the Falls, close to Goat Island, used a very little of the water of the river, and still less of its power. A small wheel below the falls, near the lower suspension bridge, used an inappreciable part of the power; this power, by rope transmission, being transferred to a mill on the upper bank. Nearly thirty years ago an hydraulic canal conducted water from above the falls and discharged it below the falls, and mills near the discharge utilized the power thus furnished. This power has been recently im-

proved by enlarging the canal and establishing turbines on the lower shore and transmitting the power by means of electricity to the upper bank.

All these efforts were insignificant compared with some recent ones. A "Cataract" Company has secured the necessary legislation for utilizing an immense power from the river. A subordinate company, known as "The Niagara Falls Power Company," proposes to utilize some 100,000 horse-power of the falls. For this purpose a short canal or bayou 250 feet wide and 12 feet deep, a mile or more above the crest of the Falls, has been excavated for this purpose, extending into the river and also into the land. This conducts the water from the river to vertical shafts at the foot of which are turbines, the discharging water being conducted to a large tunnel 7,000 feet long and about 21 feet high and 18 feet wide, which discharges into the river below the falls. The vertical fall from the surface of the water in the upper canal to the center of the wheels below is about 136 feet.

The object of "The Power Company" is to furnish power for a market. Many schemes have been proposed for utilizing the power. It has been proposed to sell it to those desiring it in the City of Buffalo; to run the cars on the Central R. R. between Buffalo and Niagara; to run canal boats on the Erie Canal; to supply light for the villages and cities along the line of this canal; and if the supply was not exhausted, to light New York and other cities. At the present time, power is supplied to manufactories which have been established near by. An immense paper mill has been erected at the entrance of the bayou, and is driven by turbines of the Jonval type.

The Power Company has put up in place two turbines of over 5,000 horse-power each. It is of these that we desire more especially to speak. They have been in successful operation for several months, and generate electricity for supplying power for the manufacture of aluminium, calcium carbide and carborumdum.

The wheels were designed by the firm of Piccard & Faesch, of Geneva, Switzerland, and built by I. P. Morris & Co., of Philadelphia, Pa. The plan of the design is shown in Figure one, which was kindly furnished the writer by Coleman Sellers, E. D., Professor of Practical Engineering in Stevens Institute of Technology, and President and Chief Engineer of the Niagara Falls Power Company.

Whether it was a fault of American manufacturers in not securing for themselves the honor of designing wheels for this place, we cannot say, but it is known that when the Niagara Commission called for designs, the American manufacturers submitted their trade catalogues, and the Europeans, special designs. The conditions under which water power exists in the two countries, and the different modes of doing business, has led to very different systems of establishing wheels. In Europe very many streams are small but have falls, and these falls differ largely; while in

this country most of the water falls are comparatively small, with abundance of water; so Americans make wheels of different capacities for average falls, and cast them in large quantitities and keep them in "stock" like store goods; while in Europe every wheel is designed for its particular place.

The power of the cast American wheel is generally determined from an actual test, and is not subject to such accurate analysis as the Fourneyron. The Power Company wished a wheel subjected to abnormal conditions, such as American manufacturers were not accustomed to. The head was about 136 feet; they desired 250 revolutions per minute, and, as privately informed, a fixed number of feet in diameter and to deliver 5,000 horse-power. We do not see the necessity of fixing the diameter, if it were so done. That done, the American wheels would be ruled out, for they are of less diameter than European wheels, but deeper. But aside from this the revolutions could not be so definitely calculated.

Other systems were discussed, such as the Pelton Wheel on a horizontal shaft; the American Twin Turbine on a horizontal shaft, so as to prevent endwise pressure on the shaft; but the large space required for the latter and the difficulty of transmitting the power to the surface prevented their adoption; and the European design, as mentioned above, secured the prize.

This wheel is a double triple wheel of the Fourneyron type, radially outflow. It is double since it is really two wheels, one below the entrance of the water through the penstock B, both of which are firmly secured to the vertical shaft. C is the casing rigidly joined to the penstock, and containing the distributors, *a, a, a.* Outside of these is the wheel containing the buckets *b, b, b.* This determines the triple character. Each wheel, above and below, being divided into three chambers by horizontal discs one inch thick and a cylindrical gate outside of the wheel, operated by the same rods, so that when the gate is one-third open the wheel will operate as if it were complete in itself with one-third the full capacity. The distributors and buckets are also shown in Fig. 1.

The radii for describing the curves of the buckets and distributors are shown in Fig. 1. The normal sections of the distributors should be greatest at the inside circumference and decrease as they approach the wheel, so that the water will have a gradually increasing velocity as it passes through them. Also the normal sections of the buckets should decrease from the entrance to the outside, as the water increases in its outward flow. In this respect we think the wheel is slightly defective, for the construction of the wheel shows that the normal section is slightly less at *a d* than at *e f*, whereas it should be the reverse.

The chief elements in determining the theoretical efficiency are the initial and terminal angles of the buckets, where the remarks in regard to the normal sections are observed. The terminal angle of the distributors for smooth running depends also on the velocity

giving maximum effect. The general expression for the speed for best efficiency is very complex. It depends upon the terminal angle of the distributors, the initial and terminal angles of the walls of the buckets, the ratio of the outside to the inside diameter of the wheel and the co-efficients of friction, and if the crowns are plane, as in this case, the ratio of the normal sections is also involved. The formulæ for this case are in the writer's work on Turbines, and are not, so far as he knows, in any other text book.

The initial angle of the bucket is given in Fig. 1 as 110° 40′, and appears to be the mean angle between the face and rear of the partition, but the writer found by comparing computations with the actual test that the face angle should be used, and by a measurement on a drawing of large scale, that the angle in this wheel is 51° for the acute angle, or its supplement 129° for the obtuse angle. The analysis of the wheel is too lengthy and uninteresting to be given here, but the less technical reader may be interested in seeing the results obtained by theory. With the data:

Inside radius of wheel	$=2\frac{5}{8}$ ft.
Outside radius of wheel	$=3\frac{1}{8}$ ft.
Inside angle of bucket	$=51°$
Terminal angle of bucket	$13° 17\frac{1}{2}'$
Coefficients of friction	Mu. 1 = Mu. 2 = 0.10
Head	= 138 ft.

The following results were found:

RESULTS GIVEN BY THE DESIGNER.

Revolutions per minute	250
Efficiency per cent	75
Velocity of entrance into bucket, feet per sec	$22\frac{1}{2}$
Terminal vel. in bucket, feet per sec	$76\frac{9}{10}$
Velocity on leaving guides, feet per sec	64.3
Velocity on quitting wheel, feet per sec	19
Angle of quitting, from radius	+23°
Velocity of inner rim, feet per sec	68.3
Velocity of outer rim, feet per sec	81.8

Some of these results differ perceptibly, and we sought, and think we found, the method of solution adopted by the designers, because the results found by this process agree almost exactly with those given.

Assuming 250 revolutions per minute the velocity of inner rim is

$$\frac{250 \times 2 \text{ Pi.}}{60} \times 2.625 = 68.30 \text{ ft. per second;}$$

and of outer rim = 81.81 ft. The triangles for velocities gives for velocity of quitting the guides, 64.31 ft. Vel. of entering the

bucket, 22.5 ft. nearly. If the ratio of the initial normal section of the bucket to that of the terminal be

$$\frac{4.275}{1.25}=3.42,$$

then terminal velocity in bucket $=3.42\times 22.5=76.95$. Vel. of quitting relative to the earth $=19$ ft.

Instead of following this plan, they may have used the more rational one of finding the terminal velocity by some formulæ of their own, finding 64.31 ft. and the velocity of the outer rim 81.81 ft. for the assumed 250 revolutions per minute; after which the other velocities would be readily found in the reverse order from those given above. It is fortunate that the results agree as nearly as they do with true theory and actual practice.

The depth of the six chambers being 1.81 ft., the terminal width as marked on Fig. 1, 1.25 in. $=0.10416$ ft. and the computed velocity 85.29 ft., the quantity of water flowing through 32 buckets will be $\frac{321.25}{12}+1.81\times 85.29=514.58$ cu. ft. per sec., and the theoretical horse-power will be $\frac{514\times 138\times 62.3}{550}=8040$ H. P. and the actual $0.834\times 8040=6700$ H. P. This result involves the supposition that the buckets are full at the outer end where the width is $1\frac{1}{4}$ in., but it has already been shown that the bucket is less at *a d* where the velocity is also less; hence 514 cu. ft. will not be discharged per sec. In order to realize the 6,700 H. P. a portion of the back vane from *f* to *c* should be removed so that the normal width of the bucket would increase continuously from *e f* to *c*. To analyze the wheel thoroughly, it should be treated as a pressure wheel from entrance to *a d*, and one of "free deviation" from *a d* to exit; but as these computations are tedious, and do not yield sufficient compensation for the labor, we will proceed in another way. The wheel might be made to conform to the above analysis by adding to the back vane from *a d* to *f e* so as to diminish the width from $1\frac{1}{4}$ in. to a proper value. A test of this wheel gave 5,500 H. P. for the capacity. This, combined with our theoretical result, would give the proper width $\frac{5,500}{6,700}\times 1.25=1.03$ in. By a different computation the writer made it 1.04 in.; which value would give, for the water discharged 433 cu. ft., for 5,500 H. P. This gives the quantity flowing through the wheel. But there is a clearance of 1-16 of an inch between the wheel and casing through which the water escapes under great pressure. By computation the writer finds that about 16 cu. ft. per second would thus escape, giving for the water entering the penstock.

$Q=433+16=449$ cu. ft. per sec. The computed leakage will be $\frac{16}{449}\,100=3.56$ per cent of the water delivered to the penstock;

or 99.44 per cent of the water passing into the penstock passes through the wheel, giving for the efficiency of the wheel referred to the water consumed $83.4 \times 0.9644 = 0.8043$, or 80.4 per cent.

We make the following abstract of a statement in regard to a test furnished by Dr. Sellers.

At the time of the test the total head from the surface of the water above the penstock to the center of the wheel was $H = 135.133$ ft., and the water delivered per minute to the penstock was $Q = 26867$ cu. ft. per min. $= 447.8$ cu. ft. per sec., and the theoretical horse-power of the water,

$$\text{H. P.} = \left.\frac{447.8 \times 135.113 \times 62.3}{550}\right\} = 6864.$$

There was an electrical out put of 5,335 horse-power; hence the actual efficiency of the wheel and dynamo combined was

$$E' = \left.\frac{5335}{6864}\right\} = 0.7785,$$

or, 77.85 per cent; and if the dynamo yielded 97 per cent as guaranteed by the makers, then the efficiency of the wheel system, including friction and leakage, would be

$$E = \left.\frac{77.85}{0.97}\right\} = 80.26 \text{ per cent},$$

and the power delivered at the upper end of the shaft would be

$$\text{H. P.} = \left.\frac{5335}{0.97}\right\} = 5500.$$

The head during this test was less than that assumed in the computation, but if 1.4 ft. for the head due to the velocity in the penstock be added, the effective head will be 136.5 ft., which is only 1.5 less than the effective head assumed. This difference will not affect the efficiency, but would affect the comparative speed. The speed was not measured, but was regulated for about 245 to 250 revolutions per minute, and the experimental efficiency and power involve an assumption; and the theoretical computation is founded on the supposition that the wheel is a pressure wheel throughout; so that it cannot be said whether a more exact analysis would agree more nearly with a test experiment, if the data were precisely the same and the quantities directly measured. As they stand, the two results—theory and experiment—agree remarkably well. The indication is—the resistances are less than those assumed, the leakage greater than that computed, and the hydraulic efficiency greater than 85 per cent of the power of the water passing through the wheel.

The volume of water may now be recomputed and will be

$$Q = \frac{5500 \times 550}{62.4 \times 136.5 \times 0.804} = 41$$

Using this result, the terminal normal width of the bucket will be

$$\text{Width} = \frac{441 \times 12}{1.81 \times 85.29 \times 32} = 1.05 \text{ in.}$$

According to our computation, the velocity of the water in the penstock will be

$$V = \frac{433}{\frac{1}{4}\, Pi.\, (7\frac{1}{2})^2} = 9.8 \text{ ft.}$$

The velocity as it enters the case will be.................. 12.2 ft.
" " in the case just before entering the distributors will be.................................. 28.5 ft.
" " entering the distributors will be.............. 30.4 ft.
" " quitting the distributors will be.............. 55.3 ft.
" " entering the wheel relative to the bucket will be. 21.3 ft.
" " quitting the bucket will be.................. 85.3 ft
" " quitting the wheel in reference to the earth will be.................................. 19.6 ft.

The main part of the shaft is a tube of steel rolled and without longitudinal riveted seam, 38 inches outside diameter and 3/8 to 3/4 inch thick. There are two solid parts joining the tubular parts, as shown in Fig. 3, which form journals for the support of the shaft and wheel, and are 11 inches in diameter. The moment of stress is

$$12\, P\, a = \frac{63{,}000 \text{ H. P.}}{n} \text{ inch pounds.}$$

For the resistance, let

r be the mean radius of the tubular shaft in inches;
t the thickness of the tube;
J the modulus of tonsional shear;
$2\, Pi\, r\, t$ will be the sectional area of the tube;
$2\, Pi\, r\, t.\, J$ will be the resisting force of the tube, and
$2\, Pi\, r\, t\, J.\, r$ will be the moment of resistance;

$$\therefore 2\, Pi\, r^2\, t\, J. = \frac{63{,}000 \text{ H. P.}}{n};$$

$$\therefore J = \frac{31{,}500 \text{ H. P}}{Pi\, r^2\, t\, n}$$

which in this case becomes,

$$J = \frac{31{,}500 \times 5{,}500}{3.14 \times (18\frac{5}{8})^2 \times \frac{3}{8} \times 252.} = 1{,}736 \text{ pounds.}$$

The torsional stress on the solid part will be given by the equation.

$$\frac{63{,}000 \text{ H. P.}}{n} = \frac{1}{2} \text{ Pi. J. } R^3.$$

in which R is the external radius of the solid part and is 5½ in.;

$$\therefore J = 8\,\frac{126{,}000 \text{ H. P.}}{\text{Pi}.\ n.\ 11^3} = 5{,}260 \text{ pounds.}$$

The resistance shear of steel or iron in large masses is not well known. If homogeneous, theory indicates that it will be 4-5 of the tenacity of the material, and the experiments indicate that the shearing resistance is nearly the same as that of the tenacity. The tenacity of mild steel is 65,000 pounds and upward per square inch, hence its shearing strength ought to be 50,000 pounds at least, according to which the solid part will be strained to about 1-10 of its ultimate strength when running steadily and delivering 5,500 horse-power, which is no more than ought to be allowed for safety, considering that in starting and stopping and for variations of loads, the stress may be considerably increased. The stress on the tubular part is small compared with that on the solid part—less than ⅓ as great. If the shaft be a uniform tube ⅜ in. thick, 19 in. radius, 140 ft. long and if the modulus of elasticity to shear be 10,000,000 pounds, then will the amount of torsion, when running steadily at 252 revolutions, delivering 5,500 horse-power, be

$$\Phi = \frac{63{,}000 \times 5{,}500 \times 148 \times 12}{10{,}000\,000 \times 2\text{P}i\ rt.\ r^2\ n,} = 0.14728,$$

which is the arc for radius unity.

The number of degrees will be

$$\frac{\Phi}{3.14} \times 180 = 8^\circ\ 26'.$$

Fig. 3 shows the penstock, shaft and relative position of the wheel. They are supported by heavy cast-iron beams resting on the solid rock.

DAVID LEONARD BARNES.

MEMBER W. S. OF E.

DIED DECEMBER 15, 1896.

Mr. Barnes was born August 23, 1858, at Smithfield, Rhode Island. He was educated at Brown University and at the Massachusetts Institute of Technology; from the former he received the degree Master of Arts. From 1879 to 1883 he was employed in the machine shops and drawing rooms of the Rhode Island Locomotive Works; in 1882 and 1883 he filled the position of Chief Draughtsman. In 1884 he was Chief Draughtsman and mechanical engineer of the Rome Locomotive Works, at Rome, N. Y.; in the same year he accepted a similar position with the Rhode Island Locomotive Works, and while there he acted also as Consulting Engineer for others.

In 1887 Mr. Barnes opened offices in Chicago and New York as consulting engineer, giving special attention to railroad equipment, elevated and street railways and electric plants. He was Consulting Mechanical Engineer for the South Side Elevated Railroad of Chicago during its construction and equipment, and

at the time of his death he was acting in a similar capacity for the Baldwin Locomotive Works and the Westinghouse Electric and Manufacturing Company in designing standard electric locomotives. He was, for several years, on the editorial staff of the Railroad Gazette, and he contributed many articles to its columns, relating chiefly to locomotive and car construction. The subject of compound locomotives was a favorite one with him, and the revised edition of "Compound Locomotives," by Arthur Tannatt Woods, contains much of his work and bears his name.

Mr. Barnes was a member of the following societies:

The American Society of Mechanical Engineers, The American Society of Civil Engineers, The Institution of Civil Engineers (of Great Britain), The American Association for the Advancement of Science, The Master Car Builders' Association, The American Railway Master Mechanics' Association, as well as the Western Society of Engineers. He was also a member of the Union League Club of Chicago, the Manufacturers' Club of Philadelphia, and the Engineers' Club of New York.

Mr. Barnes was elected a member of the Western Society of Engineers November 8, 1889; he filled the office of Treasurer of the Society during the years 1894 and 1895. He was deeply interested in all the affairs of the Society, frequently took part in its discussions, and was a member of various important committees.

Mr. Barnes was married in April, 1896, to Miss Ida S. Irwin, daughter of Col. B. J. D. Irwin, U. S. A. He died in New York city, December 15, 1896. His mother, Mrs. A. N. Barnes, of Chicago, two sisters, Mrs. George Stuart and Mrs. F. W. Sargent, and one brother, Charles J. Barnes, survive him.

Mr. Barnes loved his profession, and his activities embraced a wide field. He was an incisive thinker and a hard worker, and his analysis of intricate questions soon divested them of all accidental surroundings, and showed the main issue clearly. He thus possessed, to an eminent degree, the qualities requisite for an engineer, and these were combined with unfailing courtesy, and with the qualities of kindness and thoughtfulness for others which endeared him to all who were brought in contact with him.

By his death the Society and the profession have lost a valued member whose early attainments gave rare promise of a most useful and brilliant future.

J. W. Cloud,
C. L. Stobel,
T. L. Condron.

Western Society of Engineers,

ROOMS, 1736-9 MONADNOCK BLOCK,

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On Publication—J. J. Reynolds, Chairman; Thos. T. Johnston, W. T. Keating.

On Library—G. A. M. Liljencrantz, Chairman; G. P. Nichols, J. C. Bley.

On Membership—Alfred Noble, Chairman; H. E. Horton, Ferd. Hall.

COMMITTEE ON PAPERS.

On General Engineering—A. V. Powell, Chairman; W. B. Ewing, J. H. Spengler.

On Mechanical Engineering—A. M. Feldman, Chairman; V. Windett, Geo. E. Waldo.

On Electrical Engineering—H. M. Brinckerhoff. L. L. Summers, B. J. Arnold.

COMMITTEE ON RECEPTION.

R. P. Brown, Carl E. Davis, H. A. Boedker, B. E. Grant, F. P. Kellogg.

COMMITTEE ON REINSTATEMENT OF MEMBERS.

C. D. Hill, Chairman; C. J. Roney, D. W. Maher.

MEETINGS.

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Board of Direction: The Tuesday preceding the first and third Wednesday of each month.

ABSTRACT OF MINUTES OF THE SOCIETY.

ANNUAL MEETING OF THE SOCIETY.

Was held Tuesday Evening, January 5th, 1897, at the Technical club rooms, 228-30 South Clark Street.

The meeting was called to order at 7:30 by Thos. T. Johnston, 1st Vice-President.

Reading of the minutes was dispensed with.

Report of Mr. Emil Gerber, Treasurer, was read by him as follows:

CHICAGO, January 2, 1896.

To the Board of Direction of the Western Society of Engineers:

GENTLEMEN—I submit herewith a report of the Treasurer's accounts for the year 1896:

Balance on hand Jan. 1, 1896		$ 656 08
Received from Secretary:		
January	$1,075 65	
February	324 38	
March	497 50	
April	575 75	
May	358 10	
June	424 00	
July	896 00	
August	352 75	
September	398 60	
October	195 91	
November	229 69	
December	516 80	$5,845 13
		$6,501 21
Disbursements were as follows:		
January	$ 402 42	
February	245 08	
March	1,119 26	
April	657 21	
May	325 14	
June	811 91	
July	120 85	
August	370 83	
September	247 39	
October	599 40	
November	554 59	
December	483 71	
		$5,937 79
Cash in bank Dec. 31, 1896		563 42
		$6,501 21

The sources of revenue are as follows:

Back dues	$ 147 50
Dues 1896	3,407 00
Dues 1897	81 75
Entrance fees	390 00
Journal advertising	1,181 00
Journal sales of extra copies, half tones, etc	71 20
Journal subscription	355 50

Rent of rooms	$ 168 00	
Library	2 30	
		$5,804 25

The expenditures were for the following accounts:

Furniture and fixtures	$ 144 20	
General printing	199 65	
House expense	577 43	
Journal	2,474 54	
Library	101 28	
Services	1,956 56	
Stationery and postage	332 48	
Sundries	60 77	
	$5,846 91	
Secretary, Working Fund on hand	50 00	
		$5,896 91

The discrepancy of $40.88 between the above statement of receipts and expenditures by month and that by accounts is due to a few items appearing on both sides of account in the former, such as advance to Publication Committee refunded, postage advanced the Entertainment Committee and repaid, and a few smaller items, including interest and exchange.

The funds of the Society are deposited in its name in the American Exchange National Bank, located in the Monadnock block, in accordance with your approval.

Respectfully submitted,

E. GERBER, Treasurer.

This statement has been compared with the books of the Treasurer and Secretary and is found to be correct.

H. N. ELMER,
T. L. CONDRON,
Auditing Committee.

January 4, 1897.

REPORT OF THE FINANCE COMMITTEE.

CHICAGO, January 3, 1896.

To the Board of Direction of the Western Society of Engineers:

GENTLEMEN—At the beginning of the year 1896 the financial standing as taken from the report of the Finance Committee, dated December 19, 1895, and brought down to January 1, 1896, was as follows:

Cash in bank January 1, 1896	$ 656 08	
Unpaid dues	332 50	
Unpaid rent due from other societies	32 00	
Total assets		$ 1,020 58
1895 bills paid in 1896		232 27
Balance		$ 788 31
Library Fund (Appropriated)		102 63
Net balance		$ 685 68

This is $313.37 larger than was estimated by the last Finance Committee, principally because the expected assessment on account of the Journal was, happily, not required.

The following is the standing of the finances on January 1, 1897:

Cash in bank	$ 563 42	
Cash in hands of Secretary	50 00	
Unpaid dues	320 00	
Unpaid subscriptions to Journal	54 00	
Unpaid advertisements	1,172 00	
		$ 2,159 42
Less dues for 1897 collected	81 75	
Less subscriptions, 1897, collected	6 00	87 75

Assets	$ 2,071 67
Estimated bills payable, as stated by Secretary	1,053 16
Balance	$ 1,018 51
Less Library Fund (specially appropriated for new books)	75 00
Net assets	$ 943 51

This is a gain of $257.83 over last year. Early in the year the present Finance Committee jointly with the Publication and Library Committees prepared a budget for 1896 in which the estimated revenues were placed at $3,-680.00. This was entirely from dues of 1896, no account being made of possible entrance fees, back dues, revenue from Journal or rent to other societies, as these were too problematical and were in a measure to offset dues which might not be collected, the estimated receipts from dues being based on the then full membership.

The actual receipts for the year may be summarized from Treasurer's report as follows:

Dues for 1896 and prior	$ 3,554 50
Entrance fees	390 00
Rent of rooms	168 00
Library	2 30
Total exclusive of Journal	$ 4,114 80
From Journal	1,607 70
Total exclusive of 1897 dues	$ 5,722 50

From this it appears that we have collected 44 per cent of the dues delinquent January 1, 1896, and 91 per cent of the dues of 1896 from the membership as of January 1. The dues received from new members in 1896 together with collection of back dues have not been quite enough to make up for the uncollected 1896 dues. On the other hand, the total dues collected in 1896 plus Entrance Fees were $117.00 in excess of the estimated receipts from dues. As nearly this amount has been received, however, from entrance fees in December, it would seem safe to say that the amount due from all members at the beginning of an average prosperous year would represent about the amount that is likely to be collected from back, present and additional dues and entrance fees.

Exclusive of the Journal the net expenditures were $3,202.07 against an estimate of $3,115.00. The excess is not large and is mostly on account of Stationery and Postage and Services, while on House Expenses there is a saving.

Of the expenditure for services $212.50 was on account of the Library and the Library is further the beneficiary by $121.50 expended for shelves, etc., which, however, are carried in the Furniture and Fixtures account. The Library has, therefore, received $435.28 during the year and this expenditure has changed it from a collection of an unknown lot of books to an accessible, well indexed library.

The Journal has cost to date after deducting receipts $872.84 net, to which is to be added the estimate of outstanding bills, $706.00, making a total of $1,578.84 and from which is to be deducted the amount still due for advertising and subscriptions, leaving a probable debit balance of $352.84, which comes well within the estimate of the budget.

If to this we should add *all* of the increase of salary of the Secretary made necessary by publishing our own Journal, the increase in number of papers, etc., which is undoubtedly too much, we would have a cost of $1,152.84. Possibly a portion of Stationery and Postage should also be added. At $1,152.84, which as has already been stated is probably too high, the average cost per member for Journal has been $2.89 against $3.07 in 1895 and $3.80 in 1894. There has therefore been an actual saving in publishing our own Journal. But the greater gain is in the increased value and number of papers of our publica-

tion and in the numerous exchanges received which are estimated by the Secretary to represent an outlay of $500.

This year has been an experimental one with the Journal and while it has realized more than the most hopeful expected, the Publication Committee feels confident that the cost can be reduced in future without affecting quality. The result of this undertaking is very gratifying and the Publication Committee deserves great credit for its able management and unceasing labors.

The Society is to be congratulated on its excellent financial standing, but it should not, therefore, cease to watch its finances with great care so that there may be no step backward.

Respectfully submitted,
E. GERBER,
L. P. MOREHOUSE,
HIERO B. HERR,
Finance Committee.

Vice-President Johnston: Gentlemen, you have heard the reading of the report of the Finance Committee. This report is made to the Board of Direction and will therefore need no action on the part of this meeting, it being simply read for information. There are no other reports to consider at this time, and the next order of business will be unfinished business. There seems to be no unfinished business. The next order of business being new business, will be the announcement of the results of the election. I have here the report of the chairman of the committee which canvassed the vote, Mr. P. H. Ashmead and Mr. D. W. Maher, which the Secretary will read.

The Secretary then read the following report:

CHICAGO, January 5, 1897.

To the Western Society of Engineers:

GENTLEMEN—We, the undersigned Election Judges, appointed by the President, having duly canvassed the vote cast for the election of Officers for 1897, respectfully submit the following result:

Total number of votes received	192
Number of irregular votes, not counted	10
Total number of votes counted	182
CAST FOR PRESIDENT.	
Thomas T. Johnston	158
C. L. Strobel	22
CAST FOR FIRST VICE-PRESIDENT.	
Alfred Noble	170
C. G. Wade	10
CAST FOR SECOND VICE PRESIDENT.	
J. J. Reynolds	147
R. A. Shailer	33
CAST FOR TREASURER.	
Emil Gerber	147
C. D. Hill	33
CAST FOR TRUSTEE.	
Ferd Hall	112
D. W. Mead	67
Cast for Adoption of Proposed Amended By-Laws. "Shall the Proposed Amendment be Adopted?"	
Yes	157
No	5

P. H. ASHMEAD,
D. W. MAHER,
Judges.

Vice-President Johnston: Gentlemen, you have heard the report of the canvassing committee. What disposition shall be made of this report?

On motion the report was adopted and the following officers were declared elected:

President—Thomas T. Johnston.
First Vice-President—Alfred Noble.
Second Vice-President—James J. Reynolds.
Treasurer—Emil Gerber.
Trustee—Ferd Hall.

President Johnston: While the order of business in the by-laws calls for further proceedings at this meeting, it seems quite proper that such proceedings shall be postponed until the time of the dinner. If there is no objection, that rule will be made. Is there any other business before this meeting, if not, a motion to adjourn or take a recess is in order.

On motion the meeting adjourned to be resumed at the banquet.

The meeting being resumed in the banquet hall, Mr. Noble, 2d Vice-President, in the chair:

ANNUAL REPORT OF THE SECRETARY FOR THE YEAR 1896.

CHICAGO, Jan. 1, 1897.

To the Board of Direction W. S. E.

GENTLEMEN—I have the honor to submit the following report for your information and consideration:

At the annual meeting of the Society January 8, 1896, the records of this office showed a total membership of 399. Classed as follows:

Resident Honorary Members	1	
" Active "	259	
" Juniors	3	
" Associates	20	
Non-resident Members	113	
" " Associates	3	
	—	399
Elected and qualified to Dec. 31, 1896, since Jan. 8, 1896	30	
Reinstated 5 Resident Members, 1 non-resident Member, J. I. Kelley, Chas. Hansel, A. C. Schroder, G. H. Bremner, G. B. Springer, Frederick K. Copeland	6	
	—	36
		435

LOSSES.

Resigned to date, Dec. 31, 1895	3
	432
1895 delinquents whose time to pay dues was extended to April 1st, 1896, and failed to do so	8
	424

Resigned during the year 1896—C. H. Vehmeyer, Resident; J. G. Pearson, Non-resident; E. L. Abbott, Resident; H. F. Baldwin, Non-resident; J. H. Burnham, Non-resident; F. C. Williams, Non-resident; S. B. Jamieson, Resident Jr.; Max E. Schmidt, Non-resident; J. Stumpf, Resident; W. R. Kellogg, Resident; A. P. Vedel, Non-resident	11	
By death—G. W. G. Ferris, Non-resident; David L. Barnes, Resident	2	
	—	13
		411

Total membership January 8, 1896	399		
Total gains	36	435	
Total losses		24	
Membership December 31, 1896		411	

Classed as follows:

Resident honorary members	1	
Resident active members	272	
Resident associate members	25	
Resident junior members	3	
Non-resident active members	107	
Non-resident associate members	2	
Non-resident junior members	1	
	——	411

During the year one Associate was transferred to grade of member. There are twenty-six applications for membership in hand, which have received the favorable consideration of the committee.

During the year seventeen meetings were held in the Society rooms and one at Armour Institute.

The following is a list of papers read before the Society, viz.:

March 4, 1896, Mechanical Methods of Rock, excavation used on the Chicago Main Drainage Channel, by W. G. Potter.

April 1, 1896, Co-efficients in Hydraulic Formulae, as determined by Flow Measurements in the Diversion Channel of the Desplaines River for the Sanitary District of Chicago, by W. T. Keating.

May 6, Deep and Difficult Bridge and Building Foundations, by G. E. Thomas.

June 3, Notes About the Geology and Hydrology of the Great Lakes, by P. Vedel.

August 5, Relics Turned up in the Drainage Canal, by O. Guthrie.

August 19, Notes on Coal, by C. F. White.

September 2, Street Pavements in Chicago, by C. D. Hill.

September 16, Parks and Roads, by J. F. Foster.

September 16, Parks and Park Roads, by H. C. Alexander.

October 7, Steel Forgings, by H. F. J. Porter.

October 7, Steel for Boilers, by T. L. Condron.

October 21, Terminal Yards, by H. G. Hetzler.

November 4, Louisville and Bedford Cement, by T. T. Johnston.

November 18, Street Railway Construction, by Edward Barrington.

December 2, Electric Motors, by Edward Barrington.

December 9, The Equipment of Manufacturing Establishments with Electric Motors and Electric Power Distribution, by D. C. Jackson.

December 23, Natural Distortion of Rock in Place, by C. L. Harrison.

Lakes and Atlantic Waterway, by Publication Committee.

Catch Basin Formulae and Their Application, by Thos. T. Johnston.

Remarks on Mr. Johnston's Memo. in regard to Catch Basin Formulae, by L. E. Cooley.

All these papers have been published in the Journal of the Society, except two, one on Street Railway Construction, and the other on Natural Distortion of Rock in Place—which will appear in volume 2, No. 1.

Early in the year Mr. Chas. J. Roney, owing to ill health, was obliged to resign as Secretary, and it is but simple justice here to express a sense of the Society's appreciation of his indefatigable labors, and his fidelity to its interest at a time when he ought to have been seeking rest and restoration of impaired health. He was succeeded by Mr. Henry Goldmark, who in June, being called to Utah on business requiring an absence of indefinite period, was succeeded by the present incumbent.

The publication committee for the past year, consisting of J. J. Reynolds, chairman, and T. T. Johnston, and Chas. E. Billin, are justly entitled to congratulation for the highly satisfactory result of their labors in the publication of the Journal of the Society. The committee's report will disclose fully the details of the work accomplished and the prospectus for the new year.

THE ENTERTAINMENT COMMITTEE.

Three most delightful excursions were notable features in the year's history on the social side of the Society. The first one, August 15th to the drainage

canal, was a gratifying success; the second, October 16, 17 and 18, to the Bedford Stone Quarries at Bloomington and Bedford, Ind., and the Louisville Cement Company's Works, Louisville, Ky., was an event in which the weather, our hosts and the arrangements made by the committee conspired to render it unique and unsurpassable. The third, November 7 and 8, which included an inspection of the new bridge across the Mississippi, built by the C. R. I. & P. Ry. Co. and the Government, and designed by Mr. Ralph Modjeski; the works of the U. S. Government dam and the arsenal at Rock Island, and the western completed section of the Illinois and Mississippi Canal, with its locks and sluice-ways, constructed with concrete under the direction of Major W. L. Marshall, corps of engineers U. S. A., while not so extended as the latter, had all the elements that tend to make such an outing pleasing and profitable, as it proved to be to all the participants.

Only a brief reference to the promoters and the generous hospitalities of the hosts of these rare occasions will be alluded to in this report, as they have already received the attention of our able publication committee in the Journal of the Society.

The library has received a large share of attention at the hands of the excellent committee in charge, Mr. G. A. M. Liljencrantz, chairman, Mr. John Lundie and Mr. F. P. Kellogg.

The value of the library has been greatly enhanced by card catalogue completed during the year, so that now any book in it is readily accessible. A very considerable increase in the number of volumes on our shelves has been made through the generosity of our friends and by the committee binding periodicals having a permanent value. Our Journal, too, has been the means of putting the Society in the possession of over 160 current weekly and monthly technical papers and periodicals of interest and value to the engineering profession, which could not otherwise have been secured without a cash outlay of over five hundred dollars. Much credit is due the Committee on Professional Papers, especially Mr. John Lundie, chairman, for securing the papers read before the Society during the past year, which have proved so acceptable and interesting, as well as for providing several others yet to be read in the months to come.

Reviewing the past history of this Society, it is not discoverable that it ever stood on so firm and so broad a foundation as now, or that it ever had immediately before it outlook so auspicious. It counts in its membership many men of high rank in the engineering profession, whose sterling qualities of character and ability are not only national, but international, and with a rank and file of which any society might justly be proud, many of whom will yet carve a name high on the scroll of fame.

The membership committee reports a gratifying increase in numbers. Notwithstanding the hard times, and the additional burden which a presidential year always entails, our finances are in a most healthy condition. All things have not conspired to our success, but the balance of favor has been largely on our side.

In concluding this report, your Secretary feels constrained to state that before every member the door of opportunity stands open to a privilege as well as a duty, to add what he can to enlarge the Society's standing and increase its already broadening influence.

It is an axiom that "nothing is well done when left to mere impulse and convenience." This Society has been given an impetus in growth the past year which should be fostered, as it cannot of itself last. Papers have been prepared by members the past year that for practical value and for general interest have elicited hearty commendation at home and abroad, and has given the Society a prestige which it could have attained in no other way.

The officers and various committees have exercised diligence and discretion in directing the work of the Society, which has served to propagate an *esprit de corps* that is of utmost importance to the growth and prosperity of the Society as well as to enlarge the field of its usefulness. Therefore, the effective work needs to be followed up systematically and perseveringly if further progress is to be made.

The Journal is become the right arm of our Society, its auspicious beginning is indicative of what it can yet be, an important factor in elevating the Society to a front rank among leading scientific and technical societies—if each member will take a pride in its development and circulation. The Society has lived without it and can still exist without it, yet it can never attain the commanding position and the wide-reaching helpfulness a publication of this character will ensure by the dissemination of its own literature. It rightfully claims patronage and support which members can give without expense and a very limited outlay of time and energy in the way of preparing papers and increasing the subscription list.

The meetings are instituted for members and they can add interest and value to them by preparing and participating in the discussions, bringing prospective members to them, and by other means extend a knowledge of the scope and value of the productions of the Society and aid in increasing its membership.

Every engineer in his work has experiences and problems distinctively his own, and these develop points and suggestions in details that are invaluable to the profession. To reproduce them in the form of a paper before the Society is rendering members a practical service. At the same time the reflex action gives the writer a clearer insight into the subject and he is better fitted to do other meritorious work.

There is another feature relating to the Society I would presume to mention. It is a fact beyond question, verified in every avenue of life, and which has marked pertinency just here—that regarding the benefits a society confers—a scriptural quotation reads: "He that soweth sparingly shall reap sparingly." Always, in every organization, there are a few who reap the largest benefits, but the reason why is an open secret—these few are they who have the society's interests at heart, and upon them the burden of the labor devolves. If a member fails to become interested, no extended search for the cause need be made, the explanation is at hand. He has not taken an active part in its work, therefore has no enthusiasm in its success. Study the society's interest and seek to bring about its highest development and there will be no lack of interest. Give yourself resolutely to any work for which you have fitness, and your interest will grow into zeal.

Yet another and most vital point is a high ideal—place your standard high, work to it and for it. "There is always room at the top." I am persuaded that there is no insurmountable barrier against this Society obtaining a more forceful position in this city, nation and the world of Engineering Science. It has a future, a promised land, with little or no wilderness through which it must travel.

NELSON L. LITTEN, Secretary.

Mr. Noble: Part of the unfinished business is the reading of the report of the Publication Committee. With your permission, Mr. Reynolds will now read that report.

Mr. Reynolds then read the following report:

To the Board of Direction of Western Society of Engineers:

GENTLEMEN:—The Publication Committee beg leave to report as follows upon its operations for the year 1896:

The last annual report promised a Journal for the year, comprising six numbers, each number to contain 96 pages of reading matter, to embody papers and discussions, Topical Discussions, Abstracts and Miscellaneous matter, all to cost about $2,000.00, or less than the anticipated revenue of more than $2,200.00.

The Committee is now able to report the Journal an accomplished fact. The character of reading matter is as promised, but much more voluminous. The average of the six numbers containing 160 pages of reading matter. The revenue and cost have both been more than was anticipated; the former, including bills receivable, having been $2,827.70, and the latter, including bills payable, having been approximately $3,180.50.

The net cost of the Journal to the Society, when all bills for the year are paid, will be about $352.84 over and above the revenues directly received from

the Journal. We have on hand about 400 vols. of the Journal, from which a revenue will be derived in the future, which we think in time will make the balance on the other side.

Our exchange list comprises about 170 foreign and domestic publications and periodicals, the subscription price of which would be about $500.00. Compared with the expenditures of the Secretary in 1895 for publication, which were $1,411.45, a saving of $1,058.61 has been accomplished. As a comparison the Journal of the Association for 1895, 1,482 pages, cost $5,911.48; our Journal 1,040 pages, cost $3,180.54.

The excess of cost above revenue has been due partly to having more reading matter to present than was anticipated, the character of which we believe to have justified the additional expense; to the want of experience on our part and to the small number of subscribers obtained by the members.

While your Committee started out feeling confident of the success of the Journal, yet we felt like a young engineer about to undertake his first important piece of work, without experience, knowing that the problems we would meet would be many and difficult,—we have met these circumstances as we thought best, yet we must confess that we have paid for our experience and we can now see where we could have improved our work in a great many respects.

The first and one of the most important considerations was the finance. With nothing but the future prospects of the Journal as outlined in the minds of your Committee, we appealed to the friends of this Society for aid in the way of advertisements. The generous manner in which they responded not only insured the success from a financial standpoint, but shows that the Western Society of Engineers has friends who stand ready to support it in its endeavor to advance the profession of Engineering. And while this should be a matter of great satisfaction and encouragement to us, we should try to show our appreciation of their generosity by giving them the preference to supply our wants. Particular thanks are due to our advertisers, many of whom gave their aid to the Journal without expecting any returns, no substantial promises of profit could be given them.

The situation is different now and advertisers are found competing for desirable space. As a matter of fact, since the Journal reaches nearly 450 members of the Society, besides upward of 500 subscribers and general readers, there is no other medium through which the advertisers can so well reach their engineering customers.

During the year we have published 22 papers, containing 562 pages, while in 1895 eight papers were published and during the nineteen months previous to 1896, 192 pages. While the Committee is highly pleased with the number of papers presented, thanks to the Committee of nine (9), it desires to call attention to the fact that they were not uniformly distributed through the year. This was due, perhaps, to the fact that the committee of nine were not appointed until late in the year. A similar committee should be set to work early this year.

The members of the Society should remember that the Publication Committee cannot make a success of the Journal without the co-operation of the individual members, and we ask that each and every member consider himself responsible for his part in furnishing papers, as well as obtaining subscribers. The excuse of a great many that they have not time to write papers, is not valid and is an injustice to those who do give their time. If we all gave this excuse, we would not have a Journal nor a Society. The object for which you join the Society is not to pay your dues and hear papers read that others write. You should help your profession by adding your experience and giving your ideas. If they are good and sound, you help others ; if they are wrong, you will surely find it out, for there are always those, who, while they will not advance ideas themselves, are always ready to show you that you are wrong, and if they can do so, you are the gainer. In the first part of the year we found some difficulty to get enough papers for our Journal, but we are pleased to state that at the end of the year, we had more than we could publish, with the promise of quite a number in the near future.

The papers during the past year have been discussed much more than here-

tofore. This, we think, is due in a great measure to the advance publication. We request members to have their papers in the Committee's hands at least ten days before the date for reading of same, so that advance copies may be sent out and members be prepared for discussion. We believe the abstracts have been of great interest to our readers, and the Committee would be pleased to have the members make abstracts such as they think would be of interest. Each abstract will be marked with the initials of the member who makes it.

We are very thankful to those members who have made suggestions where they thought the Journal could be improved, and we feel sure that the Publication Committee will always be glad to have members suggest improvements and criticise their work. One of the most important points in which the Committee would ask the help of each member, is the subscription list. It is very important to the success of the Journal that we have a large subscription list, for several reasons:

It will bring a great many new members to the Society.

It brings the Society to the attention of a great many who are interested in engineering works. It will be an advantage to those who advertise in the Journal who are interested in engineering works. It will be an advantage to those who advertise, and an inducement for them to advertise in the Journal.

It will be a great help in a financial way. While it would be a great amount of work for this Committee to get 1,000 subscribers, it would require but very little exertion on the part of each member to get two or more subscribers. This would bring in the 1,000, and we wish to make a special appeal to each and every member to send us at least two subscribers. If they think they are not equal to the task, let them send in the names of two of their friends, with a check for $4.00.

During the past year we have published

562 pages of Papers and Discussions.
45 pages of Topical Discussions.
164 pages of Abstracts.
55 pages of Proceedings.
10 pages of Literary Notes.
188 pages Advertisements and Index.
6 Title.

Total, 1030 for the year.

This includes 40 full page plates, 78 smaller plates, 16 full page cuts, 33 smaller cuts, 15 tips or inserts of cuts, equal to 61 full page cuts, besides 4 profiles, equal to 65 pages.

The Journal of the Association for 1896, 810 pages.

The prospects for the year 1897 are very bright; with the experience of last year, improvements can be made in the makeup of the Journal. We can publish as much reading matter as last year, for, at least 30% less cost, while we expect to have the Journal out promptly, beginning on the 1st of February. We expect the finances to be as much as last year, and if the members will do their duty in the subscription list, we will see a very nice balance on the right side of the ledger.

The Committee is under special obligations to Mr. Nelson L. Litten, Secretary of the Society, for valuable assistance rendered in producing the Journal. He is to be thanked for the larger part of the business conduct of the work.

JAS. J. REYNOLDS, Chairman.
THOS. T. JOHNSTON.
CHAS. E. BILLIN.

Mr. Noble: We have one other item of unfinished business, the reading of the report of the Library Committee, that Mr. Liljencrantz has at hand.

The following report was read by Mr. Liljencrantz:

To the President and Board of Directors, Western Society of Engineers:

GENTLEMEN:—I have the honor to present herewith a report on the condition of the Society's Library during the year 1896.

CONTENTS OF THE LIBRARY.

At the beginning of the year there were in the library 1,715 volumes. At

the close the number was 2,325, 610 volumes having been received during the year. These figures do not include a large number of miscellaneous pamphlets and smaller publications, nor the 170, more or less, Journals and Periodicals, which have been received as Exchanges for the "Journal," thanks to the thoughtfulness and enterprise of the efficient and active Publication Committee.

CARE OF THE LIBRARY.

Although the library contains, as shown above, a goodly number of books, and among them many reference books of considerable value, it has been practically useless until recently, because of the difficulty, not to say impossibility, of finding a desired volume, by one not thoroughly familiar with the various shelves and bookcases, Engineers being generally too busy to waste time in hopeless hunting. There were, at the beginning of the year, two indexes or catalogues, viz: The Accession book and the Card Index, the latter arranged alphabetically according to authors, but both of these were unfinished. These have been referred to in a former report and need not be referred to again, except in repeating that neither would furnish the means of finding the "writings on any particular subject," which I venture to say, is the foremost requirement of an Index to an Engineering Library.

On account of this deficiency, resolutions were offered by Mr. Ferd. Hall, at a meeting held on the 5th of February, 1896, by which the Library Committee was directed to present, at a following meeting, an estimate of the amount of money and time required to prepare an Index or Catalogue, by means of which a desired volume might be found without difficulty. The resolutions were carried and a report with estimate was submitted to the Society at its meeting held on the 4th of March following. The report and estimate were received and accepted by the Society and the committee directed to act accordingly, subject to the approval of the Board of Directors.

Mr. Frank P. Kellogg, a member of the Committee, who was found to be available at the time, was engaged to do the necessary work, as planned and agreed upon by the Committee. The books were arranged according to the "Topical classification" prepared by the "Committee of Nine," and a card Index was prepared in conformity thereto. A Cabinet was purchased for this purpose—half of the payment for which was made in the shape of advertisement in the "Journal."

It should be stated here that Mr. Kellogg has, both before and after the period during which he was formally engaged for this work, spent a great deal of time and labor for and in the interest of the Library.

Invitation to members and others to contribute volumes to the Library have been quite frequent, and have been liberally responded to in many cases. Gratifying as this certainly is, it is at the same time about as embarrassing as for a poor man to be presented with a span of horses, when he has no stable, and no money wherewith to build or even rent one. I allude to the want of room in which to properly place and care for the various books and publications now on hand, but will revert to this matter later on.

EXPENDITURES FOR THE LIBRARY.

The expenditures charged to the "Library Account" during the year were as follows:

Shelving in the small room	$ 75 00
" in the large room	26 50
Two tables	20 00
One dozen Folding Chairs	9 00
Binding of books	46 50
Cabinet for Card Index	26 48
Forty-eight Pamphlet cases with stand	20 00
Mr. Kellogg's Services on Card Index	212 50
Expressage on books and miscellaneous	6 75
Total	$442 73

A small part of the above expenditures were incurred during the previous year, but they were paid for in January, 1896, and therefore included. The folding chairs and the tables might have been charged to some other account than the Library. The elimination of these items would reduce the total sum by about $30.00.

Eighty-three (83) volumes were put in readiness for the bookbinder, and the question of ordering the work done was submitted for the consideration of the Board. The order was deferred, however, the Board deeming it advisable not to incur the expense—which would have amounted to $80.25—until the coming year, when it is hoped that the finances of the Society will warrant the outlay.

A large number of "duplicates" occupy much-needed space on the shelves, and it seems desirable that these should de disposed of to the best advantage, either to members who may desire to buy them or to some dealer, and the funds so received be devoted to the purchasing of missing numbers of other works. Some provisions should also be made for the sale of extra copies of the "Journal."

USE MADE OF THE LIBRARY.

There have been no means of securing anything like correct data that would indicate the extent to which the Library has been made use of during the past year. It has, however, been consulted by many of the members as well as by Representatives of the Drainage Commission, of the Deep Water Way Commission, of the City Health Department and of the Daily Press, and so forth.

It would probably be of interest to keep, during the ensuing year, a special book for the registration of the names of those who consult the Library.

NEEDS OF THE LIBRARY.

There are some requirements that appear decidedly urgent, to facilitate the proper management and care of the Library. Among the foremost of these are: Additional shelving; a store-room in which to keep extra numbers of the Journal and other bulky matter, and the binding of all of the more important works. An estimate of the cost, in round numbers, of the needed expenses for the Library during the year 1897, is submitted as follows:

Additional Shelving	$150 00
Store-room, at $10 per month	120 00
Binding of books	200 00
Incidental expenses	50 00
Total	$520 00

With this amount made available, the Library could be made easy of access and respectable in appearance, and the rooms—especially the smaller one—would not need to look like store-rooms or back rooms of second-hand book shops.

Respectfully submitted,
G. A. M. Liljencrantz,
Chairman Library Committee.

Mr. Johnston: Gentlemen, there is one other item which comes before the meeting tonight, which I will introduce by reading a letter and a message from our President who is absent, Mr. John F. Wallace. The letter is dated New York, December 18, 1896, and is as follows:

New York, Dec. 18, 1896.

My Dear Mr. Litten:—I am on my way to Panama, sailing on the Valenco Monday, and will not be in Chicago until Jan. 20 or later. Please express my regret at not being able to attend the annual meeting of the Society to the Directors and also to the Society at the meeting. I am very sorry, but circumstances control me.

Yours truly,
J. F. Wallace.

The message is as follows:

CHICAGO, Jan. 5, 1897.

Mr. Nelson L. Litten, Secretary Western Society Engineers, City.

DEAR SIR:—I am in receipt of message from Mr. J. F. Wallace, dated at Panama, in which he expresses regret at being unable to attend the annual meeting of the Western Society this evening, and wishes that you extend his congratulations to his successor.

Yours truly,

H. U. WALLACE.

Mr. Johnston: In the absence of Mr. Wallace, Mr. Noble has kindly consented to address the meeting in his stead. I have the pleasure to present Mr. Noble.

Mr. Noble: Gentlemen, the sudden departure of Mr. Wallace from the country has deprived this Society on this occasion, of the address usually given by the retiring President. This is extremely unfortunate, for, if he had been present, we should have listened to an instructive address.

Until within the last few days it was hoped that such an address, left as a legacy, as it were, by our "departed" President, was on deposit somewhere and would be produced at the proper time; but hope faded and a day or two ago died out. The programme for this evening was thus threatened with the loss, since fully realized, of one of its most important features. Under other circumstances a perfect remedy would have been available, for the duty would have descended to our first Vice-President; but it was apprehended that that gentleman would be offered another outlet for his eloquence, and it has thus come to pass, with no good reason, that I have been asked to offer a few remarks in lieu of Mr. Wallace's address. Time has not permitted the preparation of anything more than a plain brief resume of the history of the Society for the last year.

In the country at large the year has been one of unexampled financial depression. As usual, the engineering profession has felt this more severely than any other. People must quarrel and cannot avoid sickness in evil times as in good, and the services of the lawyer and doctor are always indispensable; but the building of railroads and bridges, the erection of buildings, the development of mines and the manufacture of steel can be postponed and the engineer and the architect can be filed away until wanted. It is gratifying to know that, notwithstanding the adverse times, the Society has made steady progress in every direction.

The new constitution came in force at the beginning of the year. Its adoption, bringing higher requirements for membership and marking another stage of the development of the Society, has been followed by a great increase of interest, and, on the whole, its work has been satisfactory. A few of the by-laws seemed at times to be in the way of the convenient transaction of business, but they proved, when tested, to have a great elongation, a high elastic limit, and the reduction of cross section could be carried to attenuation without in the least impairing their efficiency. The invention of such useful material is no mean achievement in engineering.

There has been a small increase in membership. A large number of new members has been added, but the times have been so hard that some of the old members have found it impossible to maintain their membership. With the advent of better times, and with the stronger inducements the Society will be able to offer, it is hoped that most of these will renew their membership. The policy of the Board of Direction has been one of leniency in all cases of this kind.

At the beginning of the year there were

1	Honorary member,
372	Active members,
23	Associate members,
3	Juniors,

making a total of 399 Members.

During the year there was a net gain of:

7 Active members,
4 Associate members,
1 Junior,

making a total gain of 12 Members,
and a total present membership of 411.

The growth, however, is really greater than this. Twenty-six additional applicants have been voted for and are virtually members; they will be officially declared such as soon as the formality can be carried out in the manner provided by the by-laws.

The Society has lost by death during the year two of its most valued members—Mr. Ferris and Mr. Barnes. These men, who were cut down almost at the threshold of their careers, had already won world-wide reputations, and the Society, as well as the profession at large, feels their loss keenly,

On account of the Society's having undertaken the publication of its own Journal, it has been impossible to close up the business of the year as early as heretofore, and the accounts at the end of the fiscal year show $103 less in the treasury than at the beginning. This, however, is merely an apparent shortage; when the accounts of the Journal are closed for the year there will be shown a surplus above all expenses during the year of about $250. While this is not great, it is material and gratifying.

The principal event of the year in the life of the Society has been the inauguration of the publication of its own Journal. For some years it had been felt that the Society was not receiving full value for the sums contributed by it to the Association of Engineering Societies, and many believed that much better disposition could be made of its funds by undertaking the publication itself. Others doubted the expediency of this change and the present speaker was one of these. Happily, those who shared his views were in the minority and the change was made.

Two difficulties were apprehended, one, that a sufficient number of good papers could not be had from our membership to make a creditable journal; the other, that it would cost the Society much more than the publication by the Association.

As to the first of these objections, lack of material, the Journal itself is sufficient answer. A high standard was set up with the first number. Among other things it contained the most complete and valuable set of physical data relating to the important question of a deep waterway from lake ports to the seaboard, that has yet been published. Subsequent numbers have maintained this high standard. The number about to be issued will complete a volume that for amount and character of material will bear comparison with the Transactions of the American Society of Civil Engineers. Surely the Society may be proud of this result.

The financial result of the experiment has also been satisfactory. A strict comparison of the cost to the Society of its own Journal with the cost of publication through the Association is not practicable because the latter varied from year to year, but the gain to the treasury will certainly amount to several hundred dollars.

It is natural and consistent for a croaker when his predictions come to naught to justify himself by some excuse—to look for a hole to crawl out of. An anxious search shows one here. Who can say, or perhaps who can doubt, that the Journal would have been only a melancholy warning but for the extraordinary energy and ability of the Committee on Papers and the Publication Committee? The results of the work of these committees has been in part before the membership as successive numbers of the Journal have appeared. The business management has been in the hands of the Publication Committee and has been astonishingly successful. The contracts for printing and illustrations were well placed, all of the regular routine was looked after with untiring vigilance, and, best of all, orders for advertisements amounting to $2,300 were taken, and the financial success of the undertaking was assured.

This success has been so pronounced as to silence cavil; but I believe it

right to insist that to a large extent it is a personal triumph for the members of the Publication Committee. In hands less competent the venture might have proved disastrous. I believe it a matter of vital importance that the services of the present committee be retained, and a recent change in our by-laws makes this practicable. I would also urge that the gentlemen of the committee who, communicating their own enthusiasm, induced the Society to undertake this publication, owe it to the Society to make the sacrifice and continue their work. I am confident that in expressing these views I merely voice the sentiments and wishes of the membership.

The greatly increased interest in the Society is shown by the greater number of original papers offered for publication, having increased from 8 in 1895 to 21 in 1896. This remarkable growth is due almost wholly to the Journal and the agencies enlisted in its support. The exchanges obtained for the Journal, about 160 in number, constitute an important addition to the library and are a strong attraction to the reading room. Another incidental result of the publication of the Journal, of much importance to the Society, has been the development of the Secretary's office. The work of the Secretary was greatly increased by the publication and it was necessary to make more liberal provision for it. In the approximate comparison just made of the cost of our own Journal with the publication of our papers through the Association, the additional expense of the Secretary's office was included in the cost of the Journal. The propriety of this has been questioned, and in fact can only be justified by giving the Journal credit for a great part of the increased activity of its members in the Society's affairs and for a large part of the prestige gained by the Society during the year. The records and accounts have never been, in recent years at least, in as good condition as now, and it is believed that the experiment of having a fairly well paid secretary and imposing on him a large amount of work has been satisfactory to the Society as well as to the Board of Direction.

The Library has been indexed and is no longer a confused mass of unavailable books. This work was completed during the past year. Larger use is now made of the reading room, with the obvious result of increased interest in the affairs of the Society. The number of volumes has been increased during the year from 1,700 to 2,300 volumes, mostly by contributions from members and by public documents. Considerable new shelving has been procured, but much more is needed and must be provided. It has not been possible to add largely to the library by purchase during the year, but the larger income that seems assured will probably enable small additions to be made yearly, enough, it is hoped, to supply it with the more important current publications and to complete the files of several important periodicals.

At the beginning of the year, an ambitious programme was laid out, being nothing less than a complete investigation of the natural kingdoms of the earth and the operations of man therein. As a starter two committees were appointed and the work thus gaily commenced. To one of these was assigned the investigation of the rise, progress and decay of the structural materials in the old Post Office Building; to the other, a minute examination of infinity from all sides under the guise of an investigation of the properties of hydraulic cements.

Neither of these committees has been able to make a final report of its labor, but it is believed that the Society would be interested in some account of their progress.

It may be well to pause here a moment and ask ourselves, seriously, whether this programme was, on the whole, a wise one; whether it would have been for the best interests of this society or of mankind, if through the work of these committees and others contemplated, the Society had so quickly acquired, and published to the world in the Journal, full knowledge of all earthly things; most of the best incentives to effort we now know would have become wanting; there would have been almost no future for man except as an angel or a vegetable.

There is no doubt the committees have been governed by such humanitarian considerations in the conduct of their work. It is known that the Post

Office Committee has made certain observations from the windows of this room; but it may be said confidently that its report, important and interesting as it will assuredly be, will not be subversive of the existing order of things. The Committee on cement has been even more wisely conservative; so far as the speaker is aware, and he is a member of it, it has held no meetings and has done no work whatever, and by this course has involved the Society in no difficulties.

It may be permitted to allude here, obscurely, to another investigation which, it seemed to some of us, the Society might well undertake; but the opposing view of the Society was indicated with such unanimity and vigor that the subject has not been again alluded to, to this day.

The meetings during the last year have been interesting, and as a rule, well attended. The discussions, which indicate the real life and vigor of a society like ours, have been extremely valuable; the subjects of Electric Motors and Electric Traction afforded a notable instance.

During the year one of our members has performed a public service of a high and useful character in connection with the project for a deep waterway from the lakes to tide-water; two others have been assigned to responsible public duty as members of the Pacific Coast Harbor Board.

The Society has again been fortunate, as for several previous seasons, in its Entertainment Committee. The three excursions arranged by this Committee and so successfully carried out were participated in by a large share of our membership, and all will bear testimony to the completeness of the arrangements and the interest of these excursions. Such outings, placing a large representation of our membership in contact with business men of all kinds, will extend its influence widely, and the courtesies tendered by powerful business corporations are proof that its influence is now recognized. It lies upon the Society and its members to wield this wisely and for the highest interests of the profession and, therefore, for the public good.

ALFRED NOBLE.

Mr. Noble: I have now the pleasure of introducing our esteemed fellow member and most zealous worker for our Society, your newly elected President, Mr. Thos. T. Johnston.

Mr. Johnston then read the following address:

ADDRESS OF THE PRESIDENT-ELECT, THOS. T. JOHNSTON.

GENTLEMEN:—The continuous vigorous and healthy development of the Western Society of Engineers, the higher respect which it commands of thinking people year after year, the greater usefulness to which it has come, more than ever render an election to its presidency an honor for which to be thankful and in which to take pride. I thank you for this honor, and while I fully appreciate it as a gratifying evidence of respect to me as an individual, I prefer to regard it as an endorsement of a certain policy, having in view the welfare of the society, the credit for which belongs equally to all who have been directing it.

Our purpose is to advance the engineering profession. In the absence of definite instructions in our code of rules it devolves on the management of the Society to devise ways to accomplish this purpose. Many lines of action may be followed. Formerly, little else than monthly meetings at which papers were read constituted the sole line of action. Later, efforts were made to establish a library. Then came the institution of an entertainment committee which arranged for visits of the membership in a body to convenient points of engineering interest. Finally a Journal has been printed containing papers, discussions and other matters of interest. The successive Boards of Direction have had varied success along these lines in proportion to the strength of the Society, or the interest taken by the members year after year.

It may not have been practicable or useful in the past to study a course of action for a coming year, because so much uncertainty existed as to what could be accomplished. Our membership is now so numerous and represents so many branches of the profession, our organization possesses so much unde-

veloped strength and is capable of so much usefulness, that a gratifying reward may be anticipated for some consideration, at least, of what can be done.

The membership numbering nearly 450, it seems that two meetings each month will be justified for the reading and discussion of papers. In December last it required three well attended meetings to dispose of the papers to be read. Five and one-half per cent of the members will be required to produce the twenty-four papers for a year, which means that they may be easily obtained. In years past it has required some effort on the part of the management to secure papers, so that the idea of selecting subjects was not practicable. It is highly probable, however, that some choice may now be had, at least as far as part of the papers are concerned. As noted in recent issues of the daily press, the society, in a certain sense, exercises an educational function, and this statement is particularly true since the membership involves various branches of the profession, including the mechanical, electrical, structural, hydraulic and other specialists as well as the civil engineer and including what may be called a new sort of engineer who may be called a general engineer. Any paper may be instructive, even if it interests but one of the several classes of specialists. There is, however, a class of papers and discussions which will be instructive and interesting to two, three or more of the several branches, and they should be encouraged in a society of heterogeneous composition.

The subject of a paper may be a bridge and deal simply with the proportions of ties and struts, the spacing of rivets or diameter of pins. On the contrary, it may deal with the location of the bridge with reference to the character of the stream crossed, thus interesting the hydraulic engineer, and the character of foundations and masonry, thus interesting another element, and the machinery for moving the draw span, thus interesting the mechanical and electrical specialists. While papers framed on the lines first named are very desirable, still a paper on the latter lines is better adapted for inducing well attended meetings and provoking instructive discussion.

The subject may be a water works plant so framed as to treat of the source of supply and interest the sanitary specialists, treat of the conduct of water to and from the pumps or reservoir and interest the hydraulic engineer, the structural engineer or the manufacturer of pipe, and treat of the machinery and interest the mechanical and electrical engineer.

Other subjects may be handled similarly. The pump man may write his paper for the water works, the mine, the electrical, the tall building, the canal and other engineers. Having to deal with pumps, canals, bridges, tunnels, railroads, electric appliances, buildings, masonry, foundations, cements and concretes, ship-building, docks, parks, streets, water supplies, stone, drainage, mines, various materials of construction, machinery, manufacturers and other things, all subjects that can be dealt with in a general way, papers may be framed on the lines under discussion. The general engineer has to bring the specialists together and will find such classes of papers peculiarly instructive. The utility of such papers is well illustrated by the experience with a paper on electric traction read last month. The railroad man and the electrical engineer were brought in contact, provoking something like four hours of interesting and instructive discussion.

The idea of cultivating the so-called general engineer, he may be called the civil engineer by some, is well worthy of close consideration, now that engineers are so prone to follow some special branch of the profession. A city engineer may have to know of rivers and docks, bridges, water works, streets, sewers, pumps, various classes of machinery, the care and disposition of various electrical appliances, and various other things, and may be called to assemble the specialists in these several items of work which he must fit together and form into an harmonious whole. Our drainage canal has required the assembling of a great variety of specialists. Likewise has the development of the parks. The endless variety of interests brought together in constructing a large building, I take it the construction and stability of a building is the work of one engineer, is known to all. So, also, with the construction of a railroad of one kind or another. The ensuing year offers much opportunity for successful

effort in so framing the course of events that our Journal will be replete with varied information in this line if a set policy for this purpose be adopted.

The library, which was placed on such an excellent basis last year by being thoroughly indexed, may well receive further attention. Additional facilities for its care are needed, numerous exchanges received from the Journal should be bound and placed on the shelves. It is to be particularly urged that missing numbers of the files of important periodicals and transactions should be secured. It would be well if certain standard reference works which are now missing could be placed on the shelves. It does not seem practicable at this time to make any radical improvement of the library further than what may be accomplished through contributions such as have been so generously made in the past.

The Entertainment Committee, which has been so successful in the past, especially during the past year, should be encouraged and perpetuated. At least half a dozen visits to points of interest should be provided for the coming year, one or two of which may be to distant places.

The publication of the Journal can well be continued on the same lines as for the past year. While some progress was made in the matter of publishing advance copies of papers to be read and inducing liberal discussion, there is room for much further progress during the coming year.

The general policy of so framing the affairs of the Society that the interests of heterogeneous membership will best be served seems to be promising. Such a course will induce largely attended meetings and more useful discussions. It will arouse more enthusiasm and doubtless lead to much larger membership. More can be accomplished in this direction at this time by special selection of papers having this purpose in view. Later on, when the membership has become sufficiently large, other methods may be adopted.

There are gentlemen with us to-night skillful in the art of speech, instructive to their hearers and entertaining as well. You havethem with you but once a year while your president intends to be with you as often as his duties require. He therefore begs leave, with the brief remarks already made as to the policy for the year, to make way for others. The support of every member is asked in all that promotes the welfare of the Society and advances our profession. Permit me once more to thank you for the honor this day conferred.

Mr. Johnston: I have in my hand a note received this evening, which, with your permission, I will read. It is addressed to N. L. Litten, Esq.

CHICAGO, January 5, 1897.

N. L. Litten, Esq., 1737 Monadnock Building, City:

DEAR SIR: I regret that I am obliged at this late moment to notify you of my inability to be present at the banquet this evening.

Wishing for the Western Society of Engineers a most enjoyable occasion, I am,

Yours truly,

GEO. B. SWIFT, Mayor.

REPORT OF THE ENTERTAINMENT COMMITTEE.

CHICAGO, January 5, 1897.

Mr. John F. Wallace, President Western Society of Engineers, Chicago.

DEAR SIR: The Committee on Entertainment of the Western Society of Engineers begs to make the following report of its work during the year just closed:

On August 15 an excurison of the Society along the Chicago Drainage Canal was given. On this occasion the Atchison, Topeka & Santa Fe Railway tendered a special train of handsome vestibuled chair cars free of charge. About 400 members and guests, including ladies, attended. A souvenir pamphlet was prepared by your committee in which was printed a concise report of the progress of work on this important engineering enterprise. This pamphlet was handsomely illustrated and contained the advertisements of several of the contractors who had been employed or who had furnished material on the Drainage Canal.

On October 15 and 16 an excursion was given to Bedford, Ind., and Louisville, Ky. On this occasion the Louisville, New Albany & Chicago R. R. tendered free transportation to the Society. A party of 175 members and guests, including ladies, went on this trip and a train of five Pullman coaches was required to transport the party. At Bedford the party was entertained by the owners of the various stone quarries in that region. At Louisville they were the guests of the Louisville Cement Co. and others.

On November 11th an excursion to Rock Island and Davenport was given to visit the new bridge across the Mississippi River designed by Mr. Ralph Modjeski, Mem. W. S. E., and built conjointly by the United States Government and the C. R. I. & P. Ry. On this occasion the Chicago, Rock Island & Pacific Railway not only tendered to the Society a train free of charge, but also entertained the Society at luncheon and dinner on the first day of the trip. In addition to the visit to the bridge a visit was made to the United States Arsenal on Rock Island and a special visit made to the water power development now being made by the Government there. About 175 members and guests, including ladies, attended this excursion. On the second day the party visited the work on the Hennepin Canal and were entertained at dinner by the Empire Cement Co. at the Kimball House in Davenport. The fourth and last effort of your committee is laid before you this evening and needs no further description.

During the year your committee has arranged for these several entertainments and has found the means for paying all of the expenses of the same without involving the Society at all, and is glad to report that there is a small balance in hand for the committee of next year to begin operations with.

Respectfully submitted by,

G. P. Nichols,
T. L. Condron,
C. E. Schauffler,
Entertainment Committee.

REPORT OF THE COMMITTEE ON PROFESSIONAL PAPERS.

Chicago, January 5, 1897.

To the Honorable Board of Direction, W. S. E.:

Gentlemen: The Committee on Professional Papers submits this report for your information:

April 15th a Bulletin on the Dewey classification was presented to your Board, and upon consideration of its merits the secretary was directed to have it printed and a copy sent to each member of the society. The card index of our Library was subsequently made up on the basis of this classification, and appears to give satisfaction.

The following is a list of papers and dates for presentation before the Society as originally arranged.

August 19th.	"Notes on Coal"	C. F. White.
September 2d,	"Street Pavements in Chicago"	C. D. Hill.
	Discussion	R. E. Brownell.
September 16th.	"Parks and Roads"	H. C. Alexander.
	"Parks and Roads"	J. F. Foster.
October 7th.	"Steel for Boilers and Fireboxes"	T. L. Condron.
	"Steel Forgings"	H. F. J. Porter.
October 21st.	"Railway Yards and Terminals"	H. G. Hetzler.
November 4th.	"Medical Treatment of Men on Engineering Work,"	Dr. S. W. Maphis.
November 18th.	"Cableways"	Frank B. Knight.
December 2d.	"The Equipment of Manufacturing Establishments with Electric Motors and Electric Power Distribution"	D. C. Jackson.
	"Electric Traction"	Edward Barrington.
December 16th.	"Modern Pumping Machinery"	E. E. Johnson.

Of the papers mentioned, the one for November 4th was not forthcoming, and that on "Modern Pumping Machinery" will not be presented till February. At the meeting of December 22, 1896, Mr. C. L. Harrison presented a paper on the subject of "Natural Distortion of Rock in Place."

Other papers have been promised the committee and will be ready early in 1897, viz.: Steel Ties in India, Clement F. Street; The Erection of the New Rock Island Draw Span, Ralph Modjeski; Mount Wood and Top Mill Tunnels on Eastern Approach to Ohio River Bridge, Wheeling Bridge and Terminal Railway, by Wm. J. Yoder.

Yours truly,
For the Committee,
NELSON L. LITTEN, Secretary,

Mr. Johnston: It has been the custom on occasions of this kind to have conversations not only of a general nature, but of a special nature, and especially to hear from those who are our guests. We have with us this evening a representative of a sister profession, an architect, a gentleman who has been prominent in the public affairs of Chicago, has paid considerable attention to them, Mr. Patton. We will all be pleased to have Mr. Patton talk to us.

Mr. Patton: Mr. President and gentlemen, I regret that my invitation to this banquet went somewhat astray, so that it reached me at so late an hour that it was impossible for me to make connection with that dress suit which I purchased in the good old days of prosperity, and which is still in a fair state of preservation. I am not unmindful of the transforming effect of a dress suit. It so happened once with my family I took a Christmas dinner with a friend in one of the suburbs, where we were waited upon by a waiter properly arrayed in a dress suit. Coming home on the train, as I stepped out, a gentleman stepped up to me, with a smile on his face, and said, "Mr. Patton, let me assist you with your valise." He had on a checked overcoat and broad fur cap and he said, "I am not sure that you recognize me." "Well," I said, "I don't exactly place you, I think it is some time since I met you." He says, "I am the waiter who served you at dinner tonight." (Applause.)

My wife used to say that when I was dressed up I was quite a handsome man. (Laughter.) Under the circumstances I don't think I should have come here at at all if the invitation had come from anyone but an engineer; but I thought undoubtedly it was a case of constructive emergency, and I must of necessity obey the call of the engineer. This illustrates one of the advantages the engineering profession has over that of architecture brought to my mind quite recently when dealing with a building committee. Finally one member said, "Well, Mr. Patton, if this was a matter of construction, involving the safety of the building, of course we would yield to the architect; but since it is a matter of design, the committee must decide." So with architects. We can't always tell whether our plans will be carried out or not, like engineers. I should like to have had a thorough opportunity to write out carefully my, extemporaneous remarks, so as to bring before you something worthy of hearing. I did not come here with the expectation of talking. I thought most likely I should hear something from my friend, Mr. Evans, on the elevating influence of sand, especially applied to the Northwestern road. I presume it was expected that I could enlighten the company on the Municipal Improvement League. It has been rather quiet of late, and I trust that in these hard times it will not be considered altogether a confession of weakness if I say that the fact is, we are out of a job. We only had one job to start on—it was a pretty big one—and we got through it sooner than we expected, and we have not taken up anything else.

We took up the matter of the Lake Front, which, being one of those jobs which is nobody's business, we made our own, to secure a park on the Lake Front. And among other things, we architects wanted to educate the public with the idea that a few buildings located in that park or around that park would not absolutely ruin it. The general public seemed very much adverse to have any buildings anywhere near that Lake Front Park and we had to be very cautious not to put any in the middle. So we produced some very con-

servative plans on that point, and having gotten the public somewhat educated in developing that Lake Front, it next seemed advisable to turn the park over to some board, such as the South Park Board; it seemed to us the proper board to control that park. This matter, the control of the park, is a real estate matter, and the committee of the Chicago Real Estate Board, working with our League, that committee reported to the Real Estate Board and the Board gave it power to act. Then it was turned over to the South Park Board. The Mayor, seeing that printed in the papers, I suppose, at least I think two weeks after that action of the Real Estate Board, he took the matter up, and very promptly and successfully brought it to a conclusion, and the Park was turned over to the South Park Board. They having control, it being now their business, we are out of a job.

It is not the purpose of the League to prepare the plans of the buildings, or to design the buildings, or bridges or tunnels for the public. Therefore, it being under the control of the South Park Board, it is a chance for individual engineers and architects to bring forward their schemes, and the best man get the job, and that is a notice to the engineering as well as to the architectural profession; that is, it is free for all to scramble for, whatever plums there are on the Lake Front, and the Improvement League will have to try to hunt up some humble job to keep us going these hard times. We are open to suggestions.

I don't know as there is anything further to be said on that subject. I think it is a pleasant sign that engineers and architects are working together. It seems that the two professions are being brought more closely into harmony in these days when works of architecture are developing into works of engineering, so it is hard to decide whether certain works are of architects or engineers. The two must be united, and I believe that the two professions ought to be brought into closer harmony, hand in hand, each appreciating the work of the other. (Applause.)

Mr. Johnston: Gentlemen, we have with us tonight also one of our fellow members who represents the mechanical interests as applied particularly to mining and excavations. I refer to Major Lewis.

Major Lewis: Mr. President and Gentlemen of the Society: I have often wished that I was an engineer, and I never wished so more than I have tonight, for this reason, an engineer does not have to talk. An engineer does the work, and they keep parrots to do the talking. I was told yesterday that I was expected to play the parrot. I am sure, while I always feel honored to talk to such a body of gentlemen as I see here tonight, yet I always feel that it is beyond me to say anything that is instructive or that will create much pleasure, so that I rise tonight with a sinking heart. At the same time, as I said before, I feel encouraged because the wise men of this Society have the privilege of writing out what they have to say, and the other fellows have to discuss the question that they propound from memory; after a hearty dinner as we have had here, the mind does not always work as we would like to have it. It is a little bit loggy, so that one rises with considerable of a tremor, fearing that he will not be able to say that which he would like to. I know that I can not, and I know that I can not do such an occasion justice. This Society is made up of all classes of engineers. Unfortunately they come in contact with each other, of course, and the great question of today is a specialty. A man who can get hold of a specialty thinks he can earn a living and lay up something with which to pay his dues to the Western Society, as well as to the Technical Club. Unless he has that specialty it is pretty hard work.

Now I know but one engineer in this society who has a specialty. He has something all by himself in which there is no competition, and he is comparatively a young man, in age and physically, but in his mind he is awful old. He is all of eight thousand years, and that is a good while, and while we tonight sit here and discuss different questions, thinking of what Chicago is today and how it has grown in a few years, year after year, some of you know this of course, but others of you do not—so that I have a right to tell it—I say to you that there is an engineer, a member of this Society, who lived eight thousand years ago, and who engineered one of the greatest schemes that

Chicago ever saw, and that was the glacial epoch. This engineer started that ponderous creation from the upper lakes, and he drew it down through the country from the north, and brought it into Chicago, and engineered it on down the Deslpaines Valley, making a drainage canal that beats the one that we are building now, and not only that, it seems to me that he did that for a purpose. He had this whole thing in view. He saw what Chicago was going to be. (Laughter.) He knew that it would need an outlet in some direction, and the only feasible thing for him was to plow it down through the Desplaines Valley towards the Mississippi River. And while a great many were skeptical and hardly believed it—and some of them wise men, too—yet Chicago has spent about twenty-eight to thirty million dollars to prove that this engineer was right, and that he knew what he was talking about. They say they have spent it in order to drain Chicago—well, that is a side issue. But the plain issue was, to prove that our friend and fellow member, Mr. Ossian Guthrie, knew what he was talking about fifteen years ago when he told the people of Chicago what he did eight thousand years ago.

I want to say one more word in connection with this Club, as a sort of an adjunct and an annex to the Western Society of Engineers. Men have been known to die of too much wisdom, too much hard work, too much study, too much thought, and it seems to me that this Club has been organized as a sort of safety valve for that class of men. We organized it and started it here with a view of a lunch club more especially, because it is in the center of business, and Chicago is so large that we all have to live some ways from the center, and therefore this is a safety valve for men who are sitting day after day over figures and lines and curves, and all that sort of thing, until their brains get so muddled that they really do not know a straight line from a curve until they come over here to lunch; and I have seen results on that of brightening up the boys as they come here for an hour and go back to work with a renewed vigor and an energy that permits them to carry on their schemes and plans, etc., during the day with good results, and we are in hopes, gentlemen, to make this Club a success. We believe it can be done, but we need, of course, the same as everything else—support. We feel that it is every engineer's duty in this city who has engineering at heart, who has the profession in his mind, and who wishes to see it grow, that it is every one's duty to do what little they can towards supporting such a safety valve as this is by joining it and by doing all that he can, and in that way we certainly can build up an annex to the Western Society that will be a pride to all. (Applause.)

Mr. Johnston: Gentlemen, we have with us this evening a distinguished guest, Mr. Beaumont, the past President of the Illinois Chapter of the American Institute of Architects, and I am sure we will all be pleased to hear Mr. Beaumont address us. (Applause.)

Mr. Beaumont: Mr. President and gentlemen, I hoped that my brother architect, Mr. Patton, had said enough to you tonight about architecture, but I suppose in answer to your president's call I shall have to say something, so instead of talking about architecture I will talk about engineering. I have a keen appreciation for engineering, because of this reason: About twenty years ago I had occasion to come under the notice of the Chief Engineer of the London & Northwestern Railway Co., whose name, I think, was Wilson. You know the reputation of the London & Northwestern Railway for first-class railroad building. I was making a drawing of the foundation and a section of the wall that would have to stand upon it, and I did it rather rapidly, as he thought. He said, "Now, young man, how many pounds per square foot have you put upon that foundation, or propose to?" And I said, "Well, I don't know; I have put the foundation the size that I have seen other buildings with similar foundations." He said, "Now, young man, you are just beginning to learn the profession of architecture. Let me give you a little bit of advice. If you want to become a good architect, you must learn to know how to calculate your foundations and everything that go into a building" and from that moment it occurred to me how valuable was the education of the engineer. At that time the education of an architect was undoubtedly not engineering.

It has often occurred to me since that a man may become a good engineer without knowing anything about architecture, but no man can become a good architect without knowing something about engineering.

I remember a little while after that—I was working in the North of England, and we were engaged in the construction of a large building, which was to carry unusual weight on its floors. It was a six-story building, a pretty high building for that time. The plans were all finished, and the bills of quantities were taken off by the architect, and each contractor was supplied with a copy of those bills of quantities, showing the amount of iron work that was going into these buildings, etc. After these quantities had been prepared, and the contracts all in and the contracts signed, the architect found out that he had left out half of the columns in his bill of quantities. I don't know how your clients feel toward you when you have any extras in your engineering work, but our clients don't like it at all. (Laughter.) One of them said to me one day, "Now I want a building put up, but," he says, "I want you to do one thing." He says, "Do you see my hair?" I said, "Yes." "Well," he said, "my hair is gray paying extras through mistakes made by architects, and I don't want you to have any extras on this building." Well, to continue in regard to these columns left out. The architect was despairing of proceeding without an extra on the building, but he went to the iron founder and told him that half of the columns were left out, and he said, "What can you suggest in order to get over the difficulty, so that I will not have to charge up an extra against my client?" So he looked at the sections. "Why," he said, "Mr. Architect, we will cut the section of the metal in two, and it will be plenty strong enough to carry all the weight that you can put into that building. (Laughter.) And we did that, and the columns and the building are standing today. (Prolonged laughter.) Now that will give you some idea what architects twenty years ago used to know about the mathematics of building, and their education today is due to the fact that they have come in contact with the engineers. Of course, the education of an architect today is greatly more enlightened than it was twenty years ago, but I am safe in saying that it is due to societies of this kind, engineers, who show the architects how they can save their client's money, by calculating the columns or beams mathematically so that they will safely carry the weight that has to go upon them. I feel certain that the tall buildings in this city today and on the continent could not have been carried out without the engineer's assistance, and I hope, as Mr. Patton says, that the sister professions will grow closer together, and that the architect can be beneficial to the engineer and the engineer to the architect, and I hope that the good feeling which exists between the two professions will continue. (Applause.)

Mr. Johnston: Gentlemen, although the hour is growing somewhat late, there are two or three of our members from whom we would like to hear. There is one of our members present whose face we very rarely see at our regular meetings, a gentleman whom we all know very well, and from whom we will all be pleased to hear. I refer to Gen. William Sooy Smith. (Applause.)

Gen. Smith: Mr. President and Gentlemen of the Western Society of Civil Engineers: I am sorry to say that it is impossible for me at this late day in my professional career to meet with you as often as I would like to.

> You would scarce expect one of my age,
> To speak in public on the stage,
> For though I'm but small and young,
> With judgment weak and feeble tongue,
> Yet all great learned men like me,
> Once learned to write their A. B. C.

(Prolonged laughter.)

It is not because I do not feel the deepest interest in the welfare of this Society; it is not that I do not feel the deepest interest in the welfare of every member belonging to our profession. I know the discouragements encountered by those entering our Society, who come into it now prepared by a thorough education in the various technological institutes of the country; those who are educated in the great engineering departments of the great universities of the

countries entering in our profession today by the thousand per annum, more really than the needs of the country require, seeking employment in this our chosen profession. It is our duty to point out to every young man who presents himself to us, master employers, to give him every encouragement that we can. It is our duty to work for the interests of our profession to the very best of our ability. I think that it is not only the interest of every member of our profession to look out for some specialty in the profession, some particular field of labor for which he feels himself specially adapted, but seek to excel in that field. The field of knowledge that must be covered by every engineer who seeks excellence in a general way is so vast that there is no human intellect that can fully and completely cover it. It is well for us all to keep abreast with all that is developing in the various fields of engineering, to keep up our scientific acquirements, to keep up our mathematics and mechanics, and the application of both to civil engineering; but, above all, we must seek certain specialties in which we hope to excel. I think that has become the general sentiment of the profession, and so if that is followed out I think our members are on a straight road to success. Hardly a day passes when there is not from one to a half a dozen young men who present themselves to me, graduates of the various technological institutes of the country, thoroughly educated and prepared for work as civil engineers, and to whom I can offer no immediate employment. I say to them, for the present, during the present depression of public enterprises throughout the whole country, devote yourselves to anything that you feel yourselves competent to do from the education that you have received, and many a one goes out of the door thanking me for that suggestion, and I know in many instances it has resulted in securing for them almost immediate employment.

As to the work of this Society, although I have not been able to attend your meetings as often as I would like, very seldom, indeed—I was President of this Society about twenty years ago. We had a membership of about fifty then. You now have a membership, I am glad to hear, of about four hundred. This is most gratifying. That membership extends now throughout the whole western country. We are not in any rivalry with any other society that exists in the United States. We work in unison with them. We are proud to be members of the Society of Civil Engineers and also of the Western Society of Engineers. We work in unison with every society that has for its object the promotion of the welfare of our profession, the advancement of all science and the knowledge which contributes to the success of engineering. With that broad feeling of friendship for all who are working in the same line, let us go on and the future of this Society is as bright, as brilliant, as its past has been, and let this Society give its encouragement to all who propose to enter civil engineering with that broad enlightenment that makes us friends to all who are engaged in similar work. We have no rivalry except that which will stimulate us to greater endeavor. We should congratulate all those succeeding in their department of civil engineering and hold them up to the honor of the country. (Applause.) There is no profession in the country which contributes so much to the general welfare as the profession to which we belong. We should be proud that we contribute to the substantial prosperity of this city goverment more than any other profession. (Applause.)

I offer you now my apology for not being able to attend your meetings as often as I should like, but it is not from any want of interest in the Society that I am absent. I am proud to state to you this evening that we have present with us one of the most distinguished engineers of the far off Orient (applause), the projector of the great railway system of Japan; one who is a member of the railway commission of Japan. We are honored by his presence tonight, and would like to bid him God-speed in his visit that he is making to our country. He proposes to extend his visit to other countries throughout the civilized world, to increase his knowledge of the specialty to which he is devoting his talent. I refer to Mr. Shimoda, a member of the Japanese Imperial Commission of Railways. (Applause.)

I cannot take my seat without extending thanks from the bottom of my heart to the sentiments expressed by the architects here present. Our profes-

sions are intimately connected. They are connected by the knowledge which should underlie and prepare each one of us for the proper discharge of our duties. They are connected when we meet in the consideration of problems which are both architectural and engineering problems. Let us contribute all we possibly can to their success in the proper proportion of their structures from foundation to turret. Let us ask them to co-operate with us in our work. We need their assistance just as much as they need ours, and no engineer is worthy of the name who does not recognize the fact that he is not an architect, but an engineer, that the two professions are intimately associated but that they are not one. They are as distinct, but are connected as closely as any two professions can be. Let us co-operate with them and endeavor by joint effort to bring to the utmost perfection every structure that we erect, whether it is strictly of an engineering character or of an architectural one. In that way we will promote the interests in both professions, and the public interest at the same time. I do wish that all prosperity may attend this Society and that through its efforts everything will be done to advance the interests of the profession of civil engineering as united with that of architecture. Let us work all together for the common good of our country and we will be appreciated as we ought. (Applause.)

Capt. Robt. W. Hunt was then introduced by the President, and spoke as follows:

Mr. Hunt: Mr. President and fellow members of the Western Society, and I now speak to you all as guests of the Technical Club, and you are on the good, solid foundation of guests paying for what you get, therefore it makes me, as president of the Technical Club, very glad to see you here. Mr. President, this has been a most delightful evening to many of you, I trust to all, excepting myself; I have been suffering the whole evening. This has been an eventful year, sir, an eventful year to the Western Society, surely an eventful year to the Technical Club; but I came to this dinner under false impressions. Some of you, perhaps, recall a dinner which we had one year ago, a nice dinner, and we responded, some of us, to the invitation, which said it should be informal—I went there in my engineering outfit. Something was said about my pants being in my boots. (Laughter.) My face was clean; I had removed all chances of extraneous inhabitants; I had washed my hands, and I presented myself as a member of this Society and as an engineer; but I was called down and held up to ridicule by the man then approaching supreme authority in the Society. I suppose that I suffered more during the few hours of that banquet than I had ever suffered before or since, and surely thought that I had learned a lesson never again to subject myself to such indignity. We have at our corner—our office is beyond, in the Rookery—on our corner we have a clothing establishment, an establishment where they put out signs "Prices no object." Yesterday I saw that sign, and there was my relief. By promises I succeeded in getting a different outfit from the one I had last year. I have mortgaged my engineering expectations for 1897 to be here as I am to-night, and what do I find? What do I find? The man who was elected to the chief office of this Society, and, so far as my influence and vote went, by myself, is not here. Further than that, he has gone to a clime, by steamship or otherwise, which permits him probably to have no clothes on at all. I wish to heaven I had my boots! I would be insured against influenza. Wallace, God bless him! I hope he will find a pearl in every oyster which he opens, and, if he gets to Japan, may he find an angel in every servant.

But, gentlemen, this has been a most eventful year, as I said, to at least two institutions. Do you know it is astonishing how reward comes to those of deserving merit. If a man is simply single-hearted in what he does, and makes an effort, he is generally repaid for it. At that banquet, it happened one year ago, that my friend, Mr. Billin, came to me with a few lines which he had written down on the back of the menu, the names of certain gentlemen who had agreed to organize a technical club, and he said, "Now, the chances are that we are going to be inflicted with your saying something to us, and if you will kindly, by way of having something interesting to say to the people here assembled, mention this proposed technical club, we will be very much obliged

to you," and I did mention to the assembly that we wanted to organize a technical club, and it has been organized, and because I was bereft enough, or dumb enough, to do what Billin had told me to do, my friends have been blind enough to make me president of that club; and of almost all societies, outside of being president of the Society of Western Engineers, I consider that the greatest honor. Now, why? Because, here tonight, we have you where you ought to be, where the Western Society ought to be, enjoying its banquet in the halls of an engineering club. The World's Fair has come and passed. At that time we had a "Fifty Club," which tried to entertain visiting engineers, and from that came the Technical Club. During the past few months we have had distinguished electrical engineers, in fact, engineers of all professions, civil, architectural, steel and iron, metallurgical engineers, many of them from Japan, visiting Chicago, and it has been the privilege of Chicago to bring them to the Technical Club to be entertained, and we of Chicago have welcomed, and always will welcome, our good friends of Japan. (Applause.) As I had the privilege of saying to some of them last year, the "Yankees of the East," the only thing that troubles us is, what in the name of goodness are we going to make out of them? They don't drink much—I wish they did—but blandly touch their lips to the wine. Seriously, we don't want to make anything out of them; we only want to welcome them, only congratulate them. Any little nation like them who could stand up against great big China, and wipe them off the face of the earth—no, but wiped them off wherever they approached them. They are not big, but they are strong; and I learned last night how they did it. They have a poisonous serpent in Japan, a very slippery one and quite a snake. The soldier put it in a glass and poured some native wine on it, and then he drank that wine, and he was strong, and the Chinaman, "he was no good." The dragon of China went down before the serpent of Japan. Well, gentlemen, the serpent of Japan is wise as the serpent has always been. They come to us with the wisdom of the serpent. It happens, as I know, that many of you here are graduates of the Rensselaer Polytechnic Institute, and you know that for years how many classes have had Japanese in them. They laid out their program years and years ago, preparing for this advent into their nation of what we call civilization. Whether it is or not I leave for somebody else to decide. Whether they are going to be happier with this advent of our ideas, the overruling power alone can decide. They are an apt nation. Well, I hope they won't have some things which we have had. I trust that their savings banks will not fail. (Laughter.) I trust they will not learn to water their railroad stocks—I beg your pardon, sir. (Applause and laughter.) I trust, if they do water their railroad stocks, they will do it better than we have done and use purer water.

Now, with your permission, we will come to the Western Society of Civil Engineers. It was my fortune in 1893 to be elected your president—undeserved. Why it was done was beyond my comprehension, but you were blundering along, and I suppose anything looked good enough, and you made that mistake. But you did better—you gave me as strong a board of directors as the Society has ever possessed. We found you in a very deplorable condition. General Smith and preceding presidents had administered the affairs of this Society well, but circumstances—through the busy times, the care and drafts on their attention that came up, the affairs of the Society had been neglected, and you were pretty badly off. You were in debt. You were living on the income of the next year, and then not paying your debts, and radical propositions seemed to be right. They were made by us. As I tell you, I had behind me as strong a board of directors as any man was ever blessed with. The result has been what you are to-day. You are a society standing as high as—surely as high, if not higher than any local engineering society in the United States. The gentleman succeeding me, Prof. Herr, told you that you would become a national Society. We thought he was wild. I am not certain but he was right, that you will be. At all events, you are in a position now that the national societie recognize you. Your transactions of this past year—to say nothing of the value, and I will risk the value—but in quantity, equal those of the American Society of Civil Engineers, and your standing is

so now that they say to you, "Western Society, God bless you!" That reminds me of our friend, W. F. Donovan, when he was connected with the Yale & Towne people. He went down to Philadelphia and tried to sell Mr. Betz, the well-known brewer, some hardware. He was about building a new mansion. Donovan went over to sell him his hardware. He said: "Mr. Betz, after your visit abroad and looking at these pictures of the Vatican, which I find hanging on your walls, I feel you know what architecture is, and I know you want to make your house a monument to American architecture," and he replied, "Mr. Donovan, you heard of my visit to the Pope?" "Yes," said Mr. Donovan. "That was a fine visit," said Mr. Betz. "The Pope is a fine man, and he treated me fine, and he told his private secretary to give these pictures to me, and we had a nice interview, and as I came away he put his hand on my head and said, 'God bless you, John Betz, of Philadelphia,' and I put my hand on his head and said, 'God bless you, too, Pope.'" (Laughter.) So that now when these national societies are passing around their blessings, we can give them one or two back. (Renewed laughter.)

Gentlemen, we have to thank your officers of this past year for a most remarkable year. We have to thank the committee which took upon themselves the labor of the publication of our Journal more than words can express. For if it had not been their self-sacrificing and single-hearted devotion to the interests of this Society, it would have been an entire failure. Many of us have thought that we should publish our own transactions, and that committee made the Journal what it is, and I am proud that you have honored, by electing for president this year, a man who was prominent on that committee, and who did as much, if not more than any other member to bring the great success to that publication. (Applause.)

We have to thank another committee, your excursion committee. Can any of you ever forget Bedford? and the singles? Can you forget the doubles? When you were asked into breakfast? And later in the day the single-heartedness of the people on that excursion, later in the day when we got back to our train and our own or somebody else's satchels? The kind gentleman who let me take the only two glasses out of one car back into the other car to let a "sick lady" get a drink? But he followed me back and he found my "sick lady" was the Deputy Commissioner of the City of Chicago, but, nevertheless, his heart was all right. Then Louisville! That Louisville champagne lunch, where they had a table in every car and bottles on every table. Why, the beautiful sunshine! They provided that just so—well, it was immense, and then with that peculiar constancy of Kentucky hospitality as we got across the bridge, and the champagne had died away, the clouds came over, and they took us on the steamboat, and the waves rose, and the wind blew, and the atmosphere got chilly, and two great, beautiful, black servants came with that demijohn! (Prolonged laughter.) It has been an eventful year! (Laughter.) You have had a great committee, but now, do not let us get too proud, because we may lose some of these effects. It reminds me—if we construct them too large and do not anchor what we have properly—of the story of my friend, Major Harry Pickands, of a farmer up in Wisconsin, who had a pond near one of the towns—I will not specify, because you might know the man—but he had made quite a little money getting ice off the pond to supply that town. One day there was a great flock of geese settled in that pond. It was late winter, just like this one—the pond was not very deep. Well, his men came in and told him about it, a freeze came on that night, and he got up early by daylight the next morning and went over and looked at the pond, and it was just black with those wild geese tightly frozen in. He knew what wild geese would sell for in the Chicago market, and he made arrangements to get them; he sent around for his neighbors and teams, the hired men, and all got clubs to kill those geese and send them to the Chicago market. Just as they came over the hill—there was a little hill there—the geese saw them and they gave one squawk and rose up and just took the whole pond with them! (Laughter.) He lost his geese. He lost his pond, and had to plant wheat there, and it was only worth forty cents a bushel that year. (Laughter.)

Mr. Johnston: As the hour is becoming quite late, I presume a motion for formal adjournment is now in order.

On motion the meeting was then adjourned.

MEETING, JANUARY 20, 1897.

A regular meeting (the 358th) of the Society was held at the rooms of the Technical Club, 230 South Clark street, Wednesday evening, January 20, 1897, and was called to order by President T. T. Johnston.

Minutes of the previous meeting were read and approved.

Report of the Board of Direction was read, showing that since last report the following have been elected to active membership:

H. G. Hetzler, Bion J. Arnold, W. D. Sargent, R. D. Wagner, Charles V. Kerr, W. G. Price, D. W. Church, R. B. Owens, T. D. Lynch, G. M. Davidson, John Walker, R. D. Seymour, R. L. Gifford, B. L. Worden, H. E. Williams, F. E. Paradis, F. E. Turneaur, J. C. McMynn, W. H. Baldwin, John B. Allan, Harmon Trueman, E. H. Beckler.

As Associates—Frank J. Johnson, G. W. Ashby, N. L. Litten, A. S. Ross, G. S. Griscom, John T. Allison, J. H. Esson.

As Juniors—H. H. Ross, J. C. Quade.

Active Members Reinstated—G. H. Bremner, Fred. K. Copeland, G. B. Springer.

The following resignations have been received and accepted:

Active Members—C. F. White, E. C. Reynolds, R. T. Crane, Wm. Steyh, S. F. Hoge, W. F. Merrill, A. L. Grandy, Frank B. Knight, O. E. Hovey.

Junior—W. E. Syer.

Associates—J. Pajeau, E. L. Williamson, H. P. Mason.

President Johnston: The secretary hands me a memorandum which refers to a matter which I will take up at this time. As many of you know, on last Friday evening our excellent Entertainment Committee of last year took occasion to present to the Society from the funds that remained in their hands at the end of their year's work, the stereopticon which you see upon the stand. It would be highly proper, I think, for the Society to take some formal action, that might be entered upon the records, acknowledging the goodness of this committee, and the president will entertain any motion in that direction that may be made.

It was moved by Mr. Modjeski that a vote of thanks be tendered to the committee for their action. The motion was seconded and carried unanimously.

Mr. Gerber: For a number of years we have had a committee which was not provided for by the by-laws, known as the Entertainment Committee. We have just heard with what success the Entertainment Committee did its work the last year. I think it would be well to continue such a committee and I would move that the Chair appoint a new Entertainment Committee for the ensuing year, the committee to consist of five members. Seconded.

Mr. Bley: I would like to inquire why the number is increased. I understand the old committee consisted of three menbers.

Mr. Reynolds: There is more work to do.

President Johnston: That is a very good explanation. I am sure that the Committee last year had a great deal to do.

Mr. Gerber: That is about all I was going to say. I was a member of the Entertainment Committee for two years, and I know what there is to do; we did not do as much as last year's committee.

Mr. Bley: Isn't it a rule that the smaller the committee the more work it will do?

Mr. Modjeski: When I was a member of that committee the committee had to call in some more members to help them out, and I think there were five or seven.

President Johnston: There will be plenty to do for five members on such a committee. Is there any further discussion?

The motion of Mr. Gerber was put to vote and carried.

Mr. Chaunte: I received this morning a cablegram from Paris which I think is chiefly addressed to this Society. It says: "Civil Engineers who attended the World's Fair in their reunion, send their best wishes to their friends in America." I fancy that they have gotten together at the beginning of the new year and that they have remembered us. I will turn this cablegram over

to this Society and suggest that it would be a graceful thing for us to acknowledge their good wishes and to send them our best greetings. If it be desired, I will make a motion to that effect. I move that the officers of the Western Society of Engineers be authorized to send our best greetings to our French friends and to express our best wishes for their prosperity. Seconded.

President Johnston: It is certainly very gratifying to be remembered by our friends across the water and it is very proper that we should make some kind of recognition of their remembrance. Are there any remarks? If not, the motion will be put.

The motion was put and unanimously carried.

President Johnston: Is there any further new business? If not, we will proceed to the reading of the paper of the evening by Mr. Yoder. This paper is illustrated both by lantern slides taken from photographs and by slides of certain diagrams. The body of the paper does not refer directly to the photographs and it has been decided that before Mr. Yoder reads this paper the slides of the photographs will be passed through the stereopticon, one after the other, rapidly, so that we may have some conception of the character of the work.

Mr. W. J. Yoder was then introduced and read his paper entitled "Mount Wood and Top Mill Tunnels on Eastern Approach to Ohio River Bridge, Wheeling Bridge and Terminal Railway."

President Johnston: Gentlemen, you have all heard Mr. Yoder's paper and it is now open for discussion. Is there any one present who has any remarks to make with reference to the paper? Mr. Yoder spoke in the course of his paper of the question of the durability of the timber under conditions similar to those in that tunnel, or under other conditions. Mr. Chanute, will you make any remarks on that feature of the paper?

Mr. Chanute: I have had no experience in timber in mines or tunnels, and therefore I could add no information to the very excellent, admirably prepared paper which we have listened to.

President Johnston: I think the thanks of our Society are due the officers of the Technical Club for their kindness in allowing us the use of their rooms this evening, and also our thanks are due to the gentlemen who have kindly volunteered to operate the stereopticon this evening, Mr. Nichols and B. E. Grant, of our membership.

MEETING FEBRUARY 3, 1897.

A regular meeting (the 359th) of the Society was held at the Technical Club, 230 South Clark street, Wednesday evening, February 3, 1897, President Thos. T. Johnston in the chair, Nelson L. Litten, secretary, and 120 members and guests present.

The reading of the minutes of the previous meeting were dispensed with and declared approved as printed.

The Secretary read a letter from the Engineers' Club of St. Louis, Mo., requesting action on House Bill No. 9,492, relating to improvements at the mouth of the Mississippi river. Mr. Strobel moved that the matter be referred to the Board of Direction with power to act—carried.

On this occasion the President, Faculty and Alumni of the Rensselaer Polytechnic Institute of Troy, N. Y., were the guests of the Society, and representatives of the educational institutions in and near Chicago were invited tomeet these gentlemen. The attendance was very gratifying.

The early part of the evening partook of a social character. The subject selected for the evening discussion was "Technical Education." When the meeting was formally opened by President Johnston, Mr. Isham Randolph delivered a genial address of welcome. President Peck of the Troy Institute was called upon, and after responding in a felicitous manner to the welcome, took up the subject of the evening, and was followed by Director Ricketts of the same institute. The discussion was continued by President Henry W. Rogers of the Northwestern University, Evanston, Professors Ricker and Baker

of the University of Ill., Dean Thos. C. Roney of Armour Institute, Dr. G. N Carman of Lewis Institute, Prof. Judson of Chicago University, Rev. Thaddeus A. Snively and Capt. Robt. W. Hunt.

The gathering was a happy event, and while it was in the nature of a feast of reason, for the "wise men of the East" were with us, there was a thoroughly enjoyable flow of good humor throughout the evening. On motion the meeting Adjourned.

MEETING FEBRUARY 18, 1897.

The 360th meeting of the Society was held in Science Hall, Armour Institute, Thursday evening, February 18, 1897, President Thomas T. Johnston in the chair, Nelson L. Litten, Secretary, and 78 members and guests present.

The President read an invitation from the Local Committee of the American Institute of Mining Engineers, holding convention in this city, to members and visitors of the Society to accompany them on an excursion to the shops at Burnside.

The minutes of the previous meeting were read and approved.

The Secretary reported for the Board of Direction the following applications for admission to the Society:

Active Members—Frederic A. Delano, Daniel Royse, Jas. F. Clarkson Chas. P. Chase, Wm. M. McCartney.

Juniors—Harvey H. Meadows, John C. Whitridge, Wilson P. Hunt.

Associate—Arthur F. McArthur.

The report of the Committee on the Death of David L. Barnes was read and ordered printed in the proceedings of the Society and a copy sent to the family.

Mr. Reynolds moved that a vote of thanks be sent to the Committee of the American Institute of Mining Engineers for their kind invitation. Carried.

Mr. Ralph Modjeski was then introduced and read his paper entitled, "Erection of the New Draw Span of the Rock Island Bridge," which was complimented by one of the speakers in discussion as "one of the most interesting accounts of this kind that I have ever had the pleasure of listening to."

Comments, suggestions, and discussion were entered into by Messrs. Hughes, Goldmark, Carter, Johnston, Thomas, Rohrer, Modjeski, Bley and others.

On motion the meeting adjourned.

NELSON L. LITTEN, Secretary.

Chicago, February 26, 1897.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid in completing valuable volumes for our files.

Since the completion of Vol. I of the Journal, we have received the following as gifts from the donors named:

U. S. Commissioner of Education—Report for 1894-5, Vol. I and II.
U. S. Census Office—11th Census 1890. Part IV Statistics of Deaths.
U. S. Treasury Department—Commerce and Navigation, 1896.
U. S. Department of Agriculture and Forestry—Bulletins, 1891, 2, 3, 4, 5, 6.
Economical Designing of Timber Trestle Bridges, 1896.
Timber, Characteristics and Properties of Wood.
Nomenclature of the Arborescent Flora, 1897.
Report on the Use of Metal Railroad Ties, 1894.
J. J. Reynolds—Poor's Manual, 1889, 1890, 1893, 1894, 1896.
" Directory of Railroad Officials, Nov., 1894, Nov., 1895.
The Working and Management of an English Railway.
Chicago City Council Proceedings, 1880-1, 1882-3, 1883-4, 1884-5, 1885-6, 1886-7, 1887-8, 1888-9, 1889-90, 1890-91, 1891-2, 1892-3, 1893-4, 1894-5.
Railways of England, by W. M. Acworth.
J. H. Warder—13th Report California State Mineralogist, for two years ending September 15, 1896.
Specifications, etc., of Water Works Pumps, Power Plants, Electric Plants, Boilers.
Board Trustees Sanitary Dist.—Proceedings Board Trustees Chicago Sanitary District, 1895.
Chas. P. Chase—Brick Pavements.
Chas. L. Strobel—Report Commissioner General of France on Chicago International Exposition.
Catalogue of Souvenirs of French-Americans of the War of Independence.
Die Gittertrager und Lager Gerader Trager Eiserner Brucken.
Railroad Commissioners of Kansas—14th Annual Report of the Board, 1896.
H. N. Elmer, Manager The Trenton Iron Co.—Wire Rope Transmission in all its Branches.
American Book Co.—A Text Book of Plane Surveying by Wm. G. Raymond, C. E.
Dugald C. Jackson—A Text Book on Electro Magnetism, etc.
Alternating Currents and Machinery.
State Library, N. H.—Report of the Trustees, 1896.
L. E. Cooley—Table of Water Levels for the Great Lakes and St. Lawrence River.
Boston Transit Commission—2nd Annual Report for year ending August 15, 1896.
John Saltar, Jr.—Report of Board of Engineers to the Citizens' Ass'n upon Chicago Water Supply, 1875.
Proceedings of W. S. E., Vol. VI., January to July 1, 1881.
Roadmaster and Foreman—Maintenance of Way Standards.
New England's Cotton Mnfrs' Ass'n } Transactions for 1896.

Institution of Civil Engineers of Ireland } Transactions 62nd Session, 1896, Vol. XXV.

H. M. Sperry—84th Annual Report of Chief Engineer Philadelphia Water Dept., 1895.
11th Annual Report R. R. Commissioners of Kansas, 1893.
13th Annual Report R. R. Commissioners of Alabama.
Secretary of State of Arkansas.
Report Board of R. R. Commissioners of California.
Report R. R. Commissioners of Connecticut, 1893-4.
Special Report Commissioners of R. R'ds to Governor North Dakota, 1893.
2nd and 3d Annual Report R. R. Commissioners of South Dakota.
21st Annual Report R. R. Commissioners of Georgia.
Proceedings Indiana State Board of Tax Commissioners, 1893.
14th Report of the R. R. Commissioners, 1893, Kentucky.
Annual Report of the R. R. and Warehouse Commission of Minnesota.
4th Biennial Report R. R. Commission of Mississippi, 1893.
16th and 18th Annual Reports of R. R. and Warehouse Commissioners of Missouri, 1890-2.
2d and 3d Annual Reports State Board of Equalization of Montana, 1891-2.
Tables accompanying 21st Annual Report Commissioner of R.R. Michigan, 1893.
Report of State Board of Assessors and Equalization, 1891-2, Nevada.
7th Annual Report Board of Transportation, Nebraska, 1893.
Report R. R. Commissioners of New Hampshire, 1893.
2d Annual Report, Board R. R. Commissioners of North Carolina, 1892.
26th Annual Report of Commissioner of R. Rs. and Telegraph, 1893.
3d Biennial Report of Board of R. R. Commissioners of Oregon, 1893.
15th Annual Report R.R. Commissioners of South Carolina, 1893.
2d Annual Report of R. R. Commissioners of Texas, 1893.
17th Annual Report of R. R. Commissioners of Virginia, 1893.
Biennial Report of Auditor of West Virginia, 1891-2.
Annual Report State Auditor of Wyoming, 1892.
Governor's Message, Wisconsin, 1893.

The Library and Reading rooms are open from 9 a. m. till 5:30 p. m. on week-days, except Saturday, until 3 p. m.

Journal of the
Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

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IV.

ERECTION OF THE DRAW SPAN OF THE NEW ROCK ISLAND BRIDGE.

By RALPH MODJESKI, Mem. W. S. E.

Read February 18th, 1897.

PRELIMINARY DESCRIPTION OF THE BRIDGE.

Although several technical and other papers have published descriptions of the Rock Island Bridge in its general features, it will be well for those who have not read them or do not remember them, to repeat this description of the Bridge as a whole before entering into detail of the draw span.

The old bridge, of which a portion is shown in Fig. 86, was completed by the U. S. Government in 1872, with Shailer Smith as chief engineer. It crossed the main channel of the Mississippi from the Arsenal Island situated near the Illinois shore to Davenport on the Iowa shore of the river. The total length of about 1,850 feet was divided into seven fixed spans of different lengths varying from 98 ft. to 258 ft., and one draw span 365′ 7″ long. It was built as a single track railway and highway bridge, the highway floor being below the railway deck.

In 1894 an act of Congress authorized the reconstruction of this bridge and provided an appropriation for changing it into a double track railway and highway bridge.

As has already been said, the bridge joins the U. S. Arsenal grounds with the city of Davenport. The reconstruction has therefore been placed in the hands of the Ordnance department and under the immediate responsibility of Col. A R. Buffington, commander of the Arsenal. It is due to Col. Buffington that the bridge was designed without false economy and that the liberal moving load of 11,050 lbs. per foot of bridge was used in calculating the structure. Nor were any economies attempted by accepting manufacturers' specifications for material or shop work.

In designing the new bridge it was found best to use the old piers. These piers had to be lengthened to provide for the wider superstructure, which, as I said before, was to be double instead of single track. This lengthening was accomplished by changing the upper portion of the inclined cut water into one practically vertical. (Fig. 65.) No strengthening of foundations was necessary, the old piers being built on rock.

The center line of the bridge was moved up stream 18 inches.

The relative positions of the two floors were naturally preserved, the railway floor being raised two feet to allow for an increased depth of floorbeams and an increase of 6 inches in the head room for the wagon floor below.

The above general description being sufficient to render my further narrative intelligible, I shall now take up the phase of construction relating to the erection of the draw span.

GENERAL CONDITIONS.

The conditions met with in erection were the following:

1st. The contract between the Government and the contractors permitted the latter to use falsework for erecting the draw span.

2nd. No piles could be driven on account of the rock bottom of the river. The rock is at a depth of from 10 to 15 feet below the average stage of water.

3rd. Railway traffic had to be carried continually during erection. Roadway traffic was abandoned.

4th. The railway grade had to be raised 2 feet without interruption to trains.

5th. The erection of the draw span had to be done during winter when navigation is closed (from about November 15 until about the end of March) or if extended into the navigation season a provision had to be made to accommodate navigation.

An additional condition, which, as you will see, proved very important, was, that the date of the breaking up of ice in the river was not known in advance and that no falsework could be depended upon to resist a general break up of ice in the river.

The history of erection of draw span can be divided into seven periods:

1st. Erecting falsework and removing old draw span.

2nd. Erecting new turn table and portion of west (xx) arm of draw.

3rd. The accident: ice carrying away a portion of the new work.

4th. Re-establishing railway traffic.

5th. Temporary lift span.

6th. Erecting the new draw on the draw protection.

(xx) Although at Rock Island the channel of the river runs from east to west, and the center line of bridge runs nearly north and south, it will be more convenient and cause less confusion to call the Davenport end of the bridge the west end instead of the north end. Consequently the west end of draw will be the one nearer Davenport.

7th. Removing lift span and falsework and swinging new draw span into position.

I. ERECTING FALSEWORK AND REMOVAL OF OLD DRAW.

As soon as navigation was closed in November, 1895, the falsework in the west or navigable channel of the draw was placed in position. The falsework in the east arm of the draw which is never used for navigation, as well as the falsework for the 98 ft. approach had been previously erected. The falsework under the 98 ft. approach span, which carries only the railway floor spanning the roadway approach to the bridge proper was so simple as not to require any description. The falsework under both arms of the draw consisted of two stories of bents (Fig. 55). The lower

FIG. 55. FALSEWORK, TWO STORIES OF BENTS.

bents were made with eight legs and were about 35 feet wide on top and about 45 feet wide at the base. Soundings were made and the legs of each bent made of suitable length to meet the difference in depths. No bottom sills were provided, the lower ends of legs forcing themselves to bed rock through the thin layer of silt which covers it.

The bents were spaced so as to bring one bent under each panel point of the old trusses, or about 16 feet apart. As soon as the lower bents were in position, the old draw span trusses were blocked up and the lower floor demolished to admit the placing of the upper or pony bents. These pony bents were about 16 feet high and served to support the old railway floor system together with the single track. They were only about 8 feet wide on top and built of four legs and a 12 foot cap. A big

traveler, wide enough to straddle the new bridge, was erected and placed over the pivot pier.

While this work was being done, the shop work on the material for the new draw was just being commenced, and as it was uncertain when it would be finished, the contractors were not allowed to disable the old draw span, which was kept in such condition, even with the pony bents in place, that a day's work could make it capable of turning again. In this condition, that is to say with the old trusses supported on lower bents and all pony bents ready to block up the track and with the big traveler in place, several days elapsed in suspense whether to proceed with the work or to wait until the following winter. It was evident that once the old draw span removed, it would become absolutely imperative to erect the new one before the opening of the navigation due to the necessity in the navigation season of providing for both railway and river traffic. It was not at all evident, however, that the steel for the span would all be shipped in time.

At last, the contractors insisting on being allowed to proceed, permission was given them on the 23d of December by the Commanding Officer to remove the old span, and to proceed with the erection of the new one according to the contractors' original erection plans. The old iron railway floor was at once blocked up on the falsework and the old floorbeams were cut loose from the vertical posts, thus separating the trusses from the floor and making the falsework alone carry the track and its train loads. The removal of the trusses was then begun, commencing with the center panel and the turn table and going westward. The object in commencing at the center pier was to clear away the pivot pier as early as possible to permit the necessary changes in the masonry to be made and prepare for assembling the new turn table as soon as received. After the west arm was taken down, the traveler was moved back to the center and the east arm removed in a similar manner. On the 11th of January the removal of the old draw span was completed. A small traveler for the 98 ft. approach span adjoining the draw was next built and that span taken down in a few days.

While the removal of both arms of the draw was going on, the masons commenced tearing down the old pivot pier. The change in the pivot pier consisted in removing two or three top courses of the old pier and replacing them by new masonry, finishing at a different elevation. The track was supported on bents placed near the center of the pier. The stone in the rim was first removed and replaced by new masonry; this having been done, the bents were moved to the edge of the pivot pier to clear the central portion which was completed next. The pier was finished on January 21st.

Regarding the condition of the material as found in the old structure, a careful examination of some of the main pins which were all 4″ in diameter showed that they were perfectly straight; the only de-

fect was a slight pitting from rust in the spaces between the eye bars, the depth not exceeding in any case 1-32". The pin holes of the eye bars were found perfectly round except in a few cases, where the distortion was evidently due to either careless manufacture or to ramming of pins while disconnecting the old trusses. The most interesting fact is in connection with the eye bar heads. The old bridge iron was sold to a rolling mill where, when it came to cutting up the eye bars for the purpose of rerolling, it was discovered that the heads were frequently crystalline, the body of the bars at some distance from the head being invariably good iron. One of the bars, the only one which at the time of writing this had been carefully watched, when put in the shears showed a crystalline fracture with what might be called faces of very

FIG. 56.

large dimensions. The fracture was entirely crystalline at the head, and as the shears continued to cut every six inches or so, the fracture gradually presented a less crystalline appearance until at about six feet from the head the crystals disappeared entirely. This shows conclusively that in this particular case the crystals are not due to the manner in which the piece was broken as the action of the shears is a perfectly uniform one. I use the word "crystalline" and "crystals" as the best word to express the appearance of the fracture, but I doubt if in this fracture there are any crystals of a definite form.

II. ERECTING NEW TURN TABLE AND PORTION OF WEST ARM OF DRAW.

As soon as the draw was disconnected, the railway traffic depended of course on the falsework alone. At this period the river was frozen over, and it was evident that should the ice move the falsework would be carried away and railway traffic interrupted for several days. From January 21st, when the first pier was finished, until February 3rd, eleven days more passed in this uncomfortable situation, waiting for material for the new turntable. At last it arrived and work was pushed very rapidly on its erection.

It was said before that the new railway grade was to be 2 feet higher than the old one. The plan adopted to accomplish this raising without disturbing traffic was the following: To raise the adjoining 258 ft. fixed span two feet at the end next to the draw, or over pier V making an incline of it, and at the same time to raise the track on the trestle to the required height. This would allow the new floor system to be placed in position much easier. The fixed span had to be raised off the pier at any rate to allow changing of masonry. The raising of the span weighing approximately 1,000,000 pounds was accomplished by powerful jacks, using the pier as support for the end post, and two double bents, or timber towers as support for the two first panel points. While the masonry on pier V was being changed the span rested on the two double bents only, the end posts being supported by temporary diagonal rods from second panel point at the top chord to bottom of end post. Precautions were taken to have the end of the span blocked up on the masonry during the time when masons were not at work, otherwise the ice which already had shown some points of weakness by moving slightly along the west shore, could have taken out not only the draw span falsework, but also the whole fixed span by breaking the supporting tower bents.

While the work on the turn table was going on the short approach span was erected complete. On the 20th of February the first center post of the new draw was placed in position.

III. THE ACCIDENT, ICE CARRYING AWAY A PORTION OF THE NEW WORK.

On Feb. 17th the temperature was 0°, and kept very low, reaching 6° below zero on Feb. 20th. The river was low. The prospects for the ice holding out for some time were therefore very good. On the 21st the four posts of the central tower were placed in position. The temperature was zero. It was then decided to erect the channel or west arm first, and in this manner to span the dangerous channel and prevent interruption of traffic. The channel near the shore under the east arm of the draw

FIG. 57.

looked as if it would remain undisturbed even during a general breaking up of ice. The material to complete one arm of draw was on the way and expected to arrive on the 22nd, which it did. (Fig. 56 shows the four center posts erected.)

On the 22nd the thermometer rose to 24° above zero, the river remaining stationary. On the 23rd the river took a sudden rise, thermometer reading 40° above zero. This meant that the chances for a premature breaking up of ice were dangerously increasing, and as the first full panel of the west arm was being

coupled up, it became apparent that the ice would move very soon. As a precaution, the ice around and on the upstream side of the falsework was cut out, this to give a better warning in case of the ice moving. Another precaution was to keep a heavy train of old gondola cars loaded with sand on the trestle whenever the track was unoccupied by regular trains. On the 24th the situation became more critical, the river having risen 6 inches more.

Retreat was now impossible as two full panels had already been coupled up. In two days the arm could be coupled up and be out of danger. The next morning on the 25th of February the river was still rising and everything was pointing to a calamity. Nevertheless work was being pushed with desperate rapidity. The ice was from 10″ to 12″ thick and near the bridge it seemed to hold out well, but about one mile upstream, on the rapids, it was broken up and began to move around exerting an enormous pressure on the solid mass below. About 11 A. M. the calamity seemed unavoidable. Twelve hours more would save the trusses, 24 hours more would give time to support the track on the trusses and avoid interruption to railway traffic. Three double panels were coupled up, only one remaining to complete the arm.

At this critical period Mr. A. B. Milliken, in charge of erection for contractors, stationed a man on the upstream end of pier V in such a manner as not to be seen by the erecting gang on the traveler. This man was to observe the falsework and the ice and upon noticing the slightest motion in the body of ice to give a signal to the engineer of the hoisting engine to blow the danger whistle. During the lunch hour every man was made acquainted

FIG. 58.

FIG. 59.

with the danger and instructed to get off the bridge when the whistle should blow. The men aloft were cautioned against getting down too hurriedly. They had just returned to their respective duties after the noon meal when at 12:40 the danger whistle was heard. Knowing that the span could no longer be saved, the whole preoccupation centered itself on the men aloft who now descended one after the other, hurriedly but evidently with full presence of mind and without panic. Scarcely had the last man left the span when the mass of ice pressing against the falsework crushed it in on the upstream side and the traveler crumbled to pieces like a box of matches; then the steel followed with a rumbling noise. The whole mass fell on its upstream side, on top of the ice, which then carried it down with the current. The tower formed of the four center posts remained standing for a while after the rest fell and it looked as if it could be saved, although the rest of the structure remained attached to it by the top chord pins; but the pull was too great, and after swaying back and forth the two posts of the west tower-bent finally broke in two. The east bent remained standing; it was not connected to

the top chord with the rest of the structure except by temporary sticks of wood instead of pins, which sticks easily broke. The situation immediately after the accident is shown on Fig. 57. Fig. 58 and 59 show the whole mass of wreck consisting of traveler, falsework, new steel trusses, old steel floor and three or four gondola cars all mixed together barring the navigable channel. Fig. 60 shows condition of the turn table after the accident. Fig. 61 shows one of the 10 inch bars after the accident. The falsework east of the pivot pier remained in place in spite of a considerable pressure of ice. This might have been due to the weight of the sand train.

IV. RE-ESTABLISHING RAILWAY TRAFFIC.

The most serious consequence of this accident was the interruption to the railway traffic. The problem of replacing false work was made more difficult by the fact that the channel was almost entirely blocked with ice which formed practically a solid mass 10 to 15 feet deep. Fortunately the wreckage was carried beyond the center line of bridge by the pressure of ice so that very little if any of it remained in the place where the falsework was to go in. Working day and night, the trestle was built in five days and on the fifth day the first train went over the bridge again. Fig. 59 shows the temporary trestle. During this period of 5 days, the Rock Island Road took care of their traffic over other lines.

As soon as the traffic was re-established, the contractors put divers at work and commenced clearing the channel of the wreck-

FIG. 60.

FIG. 61.

age. (Fig. 59.) The channel had to be clear by the time navigation opened or about the end of March, or in about four weeks' time.

V. TEMPORARY LIFT SPAN.

It was apparent that four weeks were not sufficient to replace

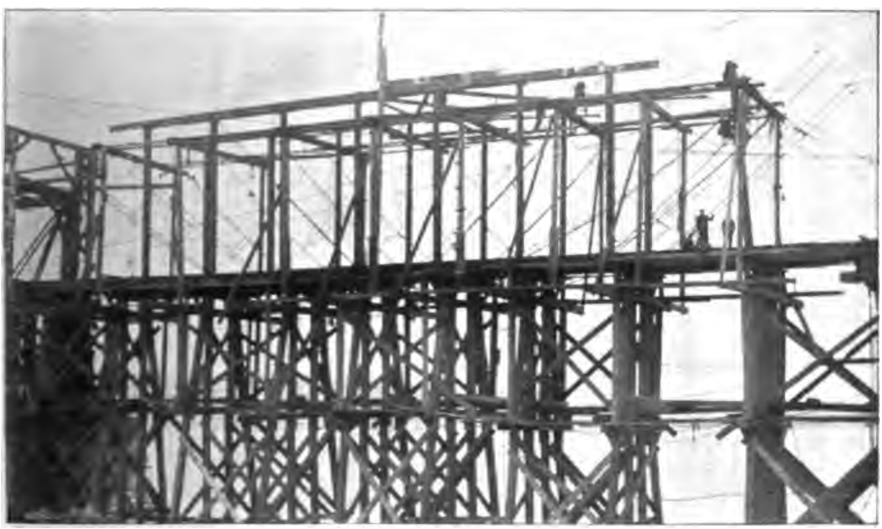


FIG. 62.

the missing members of the new draw, to erect it and put it in turning condition. Several months would be required to accomplish this. It became necessary therefore to devise some means of taking care of navigation in a temporary manner. Several means were suggested, among others, a temporary draw and a pontoon bridge. The most practicable proved to be the one suggested by Mr. E. H. Connor, resident engineer, to build a temporary lift span. Plans were immediately prepared for the towers and the contractors proceeded with the construction. The Rock Island Road happened to have a combination span on their road which was turned over to us for use on this occasion. This saved a great deal of time and material. The combination span was 147′ 5″ long and accommodated itself very

FIG. 63.

FIG. 64.

well to our problem. Nothing was changed in the combination span except additional braces were put in in the way of portals between inclined end posts. These end posts were also attached to the cast shoes by means of plates on each side bolted to both the shoe and the end post, and to the top chord by means of wooden braces. Two weeks after the wreck the erection of towers for lift span was commenced. The bents were framed on shore and taken out on barges. False work for raising the trusses of the lift span in course of construction is shown on Fig. 62.

The point of interest in the construction of the lift span is the simplicity and the success with which the suspension and lifting were accomplished. The design had to be simple so as to be quickly and easily constructed. The towers were built in two parts or stories. The lower part carrying the weight of the span and its moving load (Fig. 63) and the upper carrying only the weight of the span while lifting and forming guides for lifting. The lower part was constructed of three very strong bents braced together. The east tower rested on the river bottom near the pivot pier, the west tower rested on pier V (Figs 64 and 65). The top part destined to act as guide consisted of four 12x12 vertical posts, two on each side, which formed the guides proper; these were capped with 12x12 timbers transversely and 12x16 short timbers over each pair of guides, longitudinally. These longitudinal caps were to carry the lifting weight of the span. The vertical guide timbers were braced by means of inclined or batter posts to the lower part of tower in the east tower and attached directly to the end of

the fixed span in the west tower. Two 8x16 timbers were placed transversely under the cast end shoes of the lift span with ends projecting outside of the trusses. (Fig. 66.) These timbers carried the dead load or lifting load of the span and their ends were arranged to slide between each pair of vertical guide timbers. The suspension was accomplished by strong iron loops taking hold of the 8x16 timbers. Similar loops were attached to the longitudinal cap on top of the guide timbers. Two triple steel blocks with 15″ sheaves were attached to the two bottom loops and one quadruple and one triple at the top. 5/8″ diameter steel cable was wound around the sheaves, making 13 strands at each corner of span. No counterweight was used. As the span weighed approximately 100 tons, the strain on each strand was

Fig. 65.

FIG. 66.

4,000 pounds, adding 25 per cent. for friction, this stress was 5,000 pounds. Two double cyclinder double drum engines were obtained and placed, one on the fixed span over pier V, and one in the timber tower near the pivot pier. Each engine was to wind two cables, one from each corner of the corresponding end of span. In order to make the lifting of both corners at each end uniform the two drums were rigidly connected to engines by bolting up the friction cones. This made both drums revolve equally. The pull on each drum was about 5,000 pounds.

The towers were made of sufficient height to allow the span to be lifted 20′ 1″ which extreme position gave 65′ 0″ clearance above low water or elevation 0.0 and 44′ 11″ over highest water known. As will be seen, this clearance proved to be sufficient to let all boats pass. The highest water during the period

Fig. 67.

of operating the lift span was 10.40, leaving a clearance of 54.6 ft.
Four weeks after the accident the combination span was swung and carried the first train over. The next day the lift span was raised 6 inches on one end for trial. On the following day both ends were raised 6 ft. successfully. In the meanwhile the false-work was cleaned out and on March 26th or one month and one day after the accident we were ready to let the boats pass. We were only one day too early, as the first boat passed on the 27th.

Fig. 68.

It took about one minute to raise the span and as much to lower it. In raising it the engineer on the east end gave the signals to the one on the west end. An indicator was arranged with wires and weights to show the principal engineer if both ends of the span were keeping on the same level, and as his engine was somewhat the more powerful one of the two he could adjust the motion of his end to that of the opposite end. But even if both ends were not level, there was enough play in the guides to prevent binding. The motion of the span was very steady, without any jars or jerks, and when being lowered on its supports it would come to bearing without the least shock. Fig. 67 shows the lift span in its full length, lifted about 16 feet. The lift span was operated successfully several times a day from March 27th until

FIG. 69.

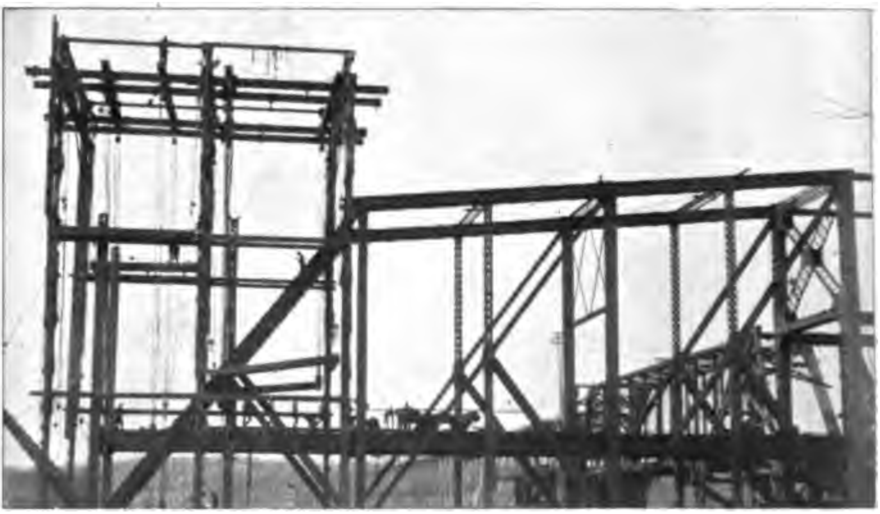


FIG. 70.

May 24th when, as will be described further, the new draw was ready to swing into its place. From May 1st until the 24th the average number of lifts per day was 14.4. On two separate dates the number of lifts reached 25 per day.

FIG. 71.

VI. ERECTING THE NEW DRAW ON THE DRAW PROTECTION.

As soon as it was decided to use a lift span it became obvious that the new draw would have to be erected up and down stream, on the draw protection. The first thing to do was to straighten the tower and examine the turn table to determine in what condition the accident had left it. The drum was jacked up to a level and the remaining bent of the central tower brought to a vertical position. Careful examination showed that the injury sustained was comparatively small. A few cast steel wheels were broken or crushed, a portion of top and bottom tread battered, and one transverse girder slightly bent horizontally in the flanges. The beveled steel treads were next removed after taking out all the wheels. This uncovered the perfectly level surface of the cast iron lower track and the surface of the bottom flange of the drum which should be level. The drum was then lowered on to the cast iron track, to ascertain how much the shape of the drum had suffered in the wreck. It was found that in two places the flange of the drum did not touch the lower track, indicating that it had been crushed in. The deviation from a true plane did not exceed ½". In this position, the drum was clamped down to the track and the injured spots corrected by cutting out rivets in the lower flange angles, forcing these angles down to contact with the surface of the track, reaming out the rivet holes to a larger size and redriving the rivets.

As to the material which fell into the river, the contractors took the wisest possible action by reordering everything new ex-

FIG. 72.

FIG. 73.

cept the turn table and one tower bent which survived, and not attempting to save a few pieces here and there.

The drum was next lifted bodily with the remaining two posts, the treads and wheels were put into place and the drum lowered down again. Fig. 68 shows the turn table and the two posts

FIG. 74.

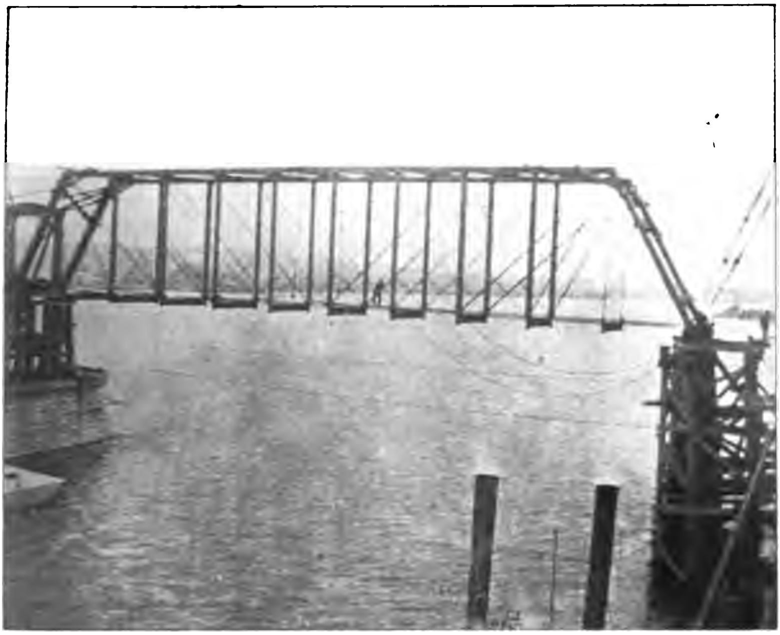


FIG. 75.

FIG. 76.

Fig. 77.

straightened out. It became necessary to turn the drum 90 degrees in order to continue the erection of the draw on the protection. This was done in a few hours on March 27th, or on the same day that the first boat passed under the lift span. Figures 69 and 70 show the different stages of erection of the down stream arm.

It will be noticed that owing to the fact that the tower supporting the lift span at the end nearest to the pivot pier was built not on the pier but in the river, the turning of the drum 90 degrees as well as the transfer of the traveler from the down stream to the upstream side could be made without interfering with the lift span, by simply disconnecting the track for a few hours.

The draw was connected on April 12th and riveted up and ready to swing into place on or about May 21st. It was necessary to lay a track on the draw span so that when swung into place the track would be already laid, also to prepare everything as far as possible for the day when the first swinging would take place, and have all work done as far as possible, because once the draw swung, it would be operated several times a day rendering most of the work more difficult and some of it impossible. This made it also necessary to put the greater part of the machinery in place and do most of the riveting before swinging. Hence the long time spent from April 12th to May 21st. Fig. 71 shows the draw span ready for swinging. It also shows the lift span to the right of the pivot pier and the falsework with the old floor system to the left.

VII. REMOVING LIFT SPAN AND FALSEWORK AND SWINGING NEW DRAW INTO PLACE.

May 25th was the date set as the most convenient day for the Railway Co. for the swinging of the new draw. The work to be done before the draw could be turned around was: 1st the removal of the lift span, 2nd the removal of the old floor and falsework in the east arm of the draw, and 3rd the changing of track in the center panel of the draw span by turning it around 90 degrees. (Fig. 72.) All this had to be done in 10 hours, the maximum time allowed by the Railway Co. Monday was selected due to the small number of trains on that day. No through passenger trains were to be interfered with.

It was decided to remove the lift span by lowering it on barges. The falsework and old iron floor in the east arm was to be removed panel by panel, with a specially constructed derrick car shown on Fig. 73. The change of floor in the center panel was a simple matter. Three separate gangs would be put to work so as to perform the different operations simultaneously.

On Sunday afternoon the navigation was closed by order of the Commander of the Rock Island Arsenal, to be reopened again the following day as soon as the lift span was removed. At 2:40 P. M. on Sunday the last boat passed under the lift span and im-

FIG. 78.

FIG. 79.

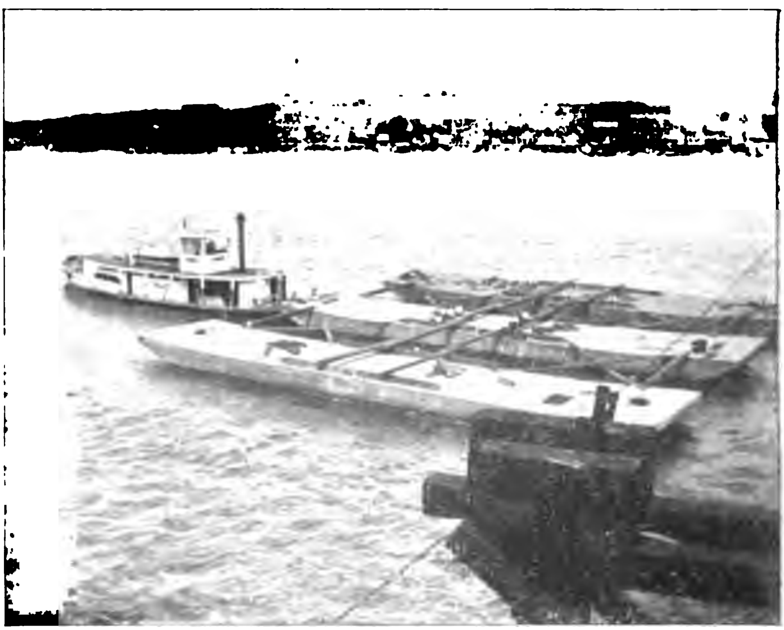


FIG. 80.

FIG. 81.

FIG. 82.

mediately after, the work on preparation for lowering the lift span was commenced. The upper portion of the two towers, in other words the guides and their braces, also the engine in the tower next to pivot pier were first removed. This work of course did not interfere with the trains, but by disconnecting the lifting device made navigation for high boats impossible. In this way the lift span became a fixed span resting on the lower portions of the wooden towers. (Fig. 74.) Chains and slings, by means of which the lift span was to be lowered, were placed in position. The east end of the span was suspended from the tower of the new draw, the west end from top of the end posts of the adjoining old fixed span. On the other side of the pivot pier, the old floor system had been cut apart sufficiently to facilitate removing it panel by panel. All this work was finished on Sunday afternoon. On Monday morning early everything was in readiness. At 7:35 A. M. the last train crossed the bridge and immediately after, a gang of railway men began removing the track and wooden stringers from the lift span. (Fig. 74.) This proved to be a slow operation, taking nearly four and one-half hours; at noon the floor was stripped of everything but the floorbeams. (Fig. 75.) While this was being done, another gang was putting in the counters in the middle panel of the draw (Fig. 76), while the

FIG. 83.

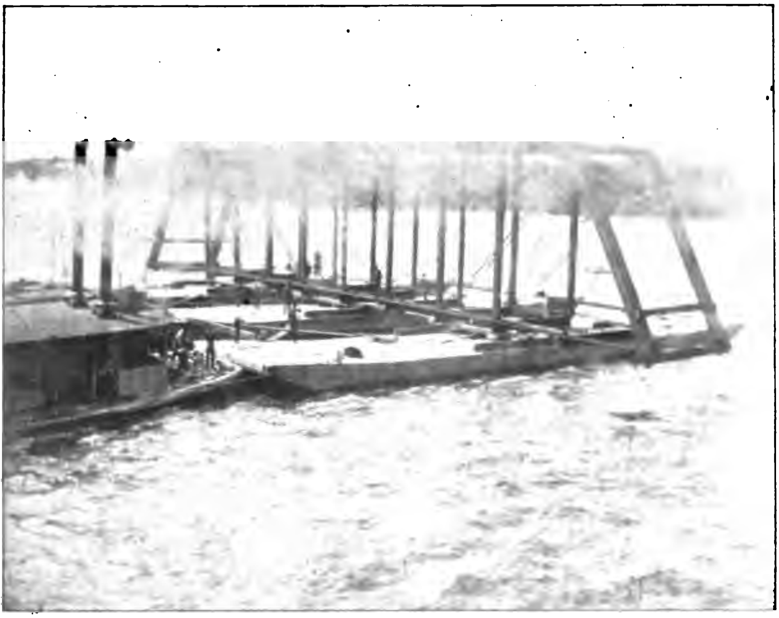


FIG. 84.

third gang brought the special derrick car on the trestle and commenced its work (Fig. 77), continuing it the whole day, taking out one panel at a time.

Soon after the work of stripping the floor of the lift span was finished, the span was raised off the supporting towers with the temporary chains and blocks and about 1:30 the west tower was pulled over into the river and was floated off. (Fig. 78.) Twenty-three minutes later the east tower splashed into the water. (Fig. 79.) It will be remembered that this tower was resting directly on rock and not on piles. At this moment the three barges prepared for carrying away the lift span, and pushed by two small steamers, were signalled to approach. (Fig. 80.) The three barges were rigidly attached together and spread out so as to support almost the whole length of span. Two lines of stringers were placed on them on which the floor beams of the span were to rest. The span was now suspended (Fig. 81) and was being slowly lowered. (Fig. 82.) When it reached a height of about ten or twelve feet from the water, the barges were steered under it and the span lowered until it rested on them. (Fig. 83.) The slings and chains were removed and barges and span floated away towards shore (Fig. 84). It took less than three hours from the time the span was stripped of its track and stringers to the time when it was sailing away. These three hours included 30 minutes for dinner, leaving 2½ hours of actual work. For this

FIG. 85.

good record credit is due to the Contractors' foreman, Mr. H. D. McKee, who proved to be a good general in managing his men and laying out work for his gangs. It should be remarked that as soon as the lift span was out of the way navigation was opened. The first boat passed about 3 P. M. The actual time of closed navigation was 24 hours 20 minutes. While the lift span was thus sailing away the work east of the pivot pier was not finished but was progressing steadily. The derrick car would lift one panel of the iron floor and deposit it on shore, then it would return and lift off the corresponding pony bent, which instead of being deposited on shore would, for sake of time saving, be lowered along side of the lower bent and attached to it, and so on alternately, each panel taking approximately one hour. The lower portion of falsework was left in place because it would clear the swinging draw span. Before the last bent was lowered, ropes were attached to the end of the draw and connected with a hoisting engine placed on shore for the purpose of operating the draw temporarily, and then the most exciting event happened: The huge mass of steel weighing 2,500,000 lbs. began actually though noiselessly to turn. (Fig. 85.) All doubts whether the draw would ever be able to turn were settled. Remained another doubt: Will the draw fit into place? It looked at one time as if it was about to interfere with the abutment by several feet. This doubt was soon settled, too, and the draw was swung into its place at 5 P. M. Temporary blocking was arranged at the end of the draw, as the end lift apparatus was not yet in working order. At 6:10 P. M. the draw was ready for trains. The actual time of in-

FIG. 86. OLD BRIDGE BUILT IN 1870.

terruption to traffic was 10 hours 35 minutes. It would have been less if several boats had not come soon after the draw was swung,

FIG. 87. NEW BRIDGE.

requiring it to be opened and thereby interfering with the work of rigging up temporary blocking on the ends.

In the above paper I have gone into more details than may prove of interest to bridge engineers, to whom much of what I have said is quite familiar, but I trust that there are other members of the Society following other lines of engineering, or not having experience in field work, to whom those details may prove of some interest.

DISCUSSION.

Mr. Henry Goldmark: There is certainly food for reflection in this paper, though I feel hesitation in speaking on the subject without giving it more time than I have been able to.

The whole history of this wreck seems to prove that the engineers and contractors in charge showed great skill and energy in replacing the work that had fallen. I think it is certainly one of the most interesting accounts of this kind that I have ever had the pleasure of listening to. We all know that as long as the time during which erection can take place is limited, as long as the favorable conditions of ice and river currents have to be taken into consideration, such accidents will inevitably occur from time to time. But I think the engineers in charge have every reason to congratulate themselves upon the brilliant success with which the traffic was restored and maintained and particularly the extremely interesting way in which the temporary movable bridge was built and operated, and in which the draw-bridge was finally swung into position. I do not know any more interesting example of a movable bridge than this lift-bridge which Mr. Modjeski has shown us.

There has been of late years a great deal of discussion as to the best form for movable bridges, and in this city a number of different types have been built. The lift-bridge described, although built for a temporary purpose, has shown by its success that there are places where the same form of bridge would be an extremely good permanent structure.

There are a great many places throughout the country where a movable bridge is required by law, but where there is very little navigation so that the bridge is rarely opened. I have met with more than one railroad draw-bridge that has never been turned at all since its first construction. There are many more which are used only a few times each year. For such locations the clear height required when the bridge is opened is usually moderate, and in this case a lift span has long seemed to me to possess many advantages over the ordinary swing bridge. When closed it is a simple truss, and is a far better structure for trains to cross at high speed. The cost of the substruct-

ure will almost always be much less, and the metal work need not cost any more.

When great vertical clearance is required—say 70 ft. to 150 ft. —the case is different. The towers and their bracing become heavy and unsightly and the machinery for moving the bridge is cumbersome and expensive both in construction and operation. For such high lifts other types are much cheaper and better.

In 1882, when I was connected with the Engineering Department of the West Shore Railroad, we erected a lift bridge across the Erie Canal at Syracuse. It is 104 ft. long on a skew, with a lift of about 8 ft.; it has a tower at each end, is counter-weighted and lifted by a simple hydraulic machinery. This is a double-track bridge, on a trunk line, and has always, as I understand, given perfect satisfaction. I think for this place we could not have selected a better form of bridge.

I am very glad that Mr. Modjeski has told us how satisfactory this improvised structure was. It certainly must have been designed with care and with practical sense and judgment, because, simple as it was and hastily built, it did its work so very well.

This is simply a single point that was suggested by the paper, and many other questions have undoubtedly suggested themselves to other members.

Mr. Geo. E. Thomas: From the description given by Mr. Modjeski I think a similar method was used in raising the bridge over Missouri River at Glasgow in 1879; owing to pressure of drift wood, etc., one span of this bridge fell during course of erection. This accident caused the old American Bridge Co., who had contract for river spans, to turn their work over to the C. & A. R. R. Co.

Gen. W. Sooy Smith, who was consulting engineer for the R. R. Co., then adopted a different plan of false work, viz.: he put in one false pier between the two main piers and clamped around each of those a heavy bolster of timber, using two spans of 150′ each, resting one end of each of those on a temporary or false pier built on piling between the main pier, the other ends resting on bolsters on main pier, in this way allowing a free passage for the drift, etc., and on those spans raised the permanent steel spans of 315′ each, and as soon as one steel span was completed he lifted the temporary span on false work erected on barges, and carried them into the next opening and in this way successfully crossing the river.

I congratulate Mr. Modjeski on his success and I am sure his description of the bridge, especially the draw span, has been very interesting to me.

Mr. E. E. Johnson: As I am entirely unable to discuss the matter, I presume I may be permitted to ask questions. At the top of page 140 of the paper is a very interesting subject to all, I am sure. The writer states that one of the bars when put in the shears showed this crystalline fracture, and the specimens on the

table clearly illustrate what he means. I presume from the text that no tests were made, but I would like to ask what Mr. Modjeski's judgment is as to the effect of this crystallization upon the strength of material and, second, what conditions of stress produce the change and what the effect would have been had the old structure been left longer in service.

Mr. Ralph Modjeski: These questions are very difficult to answer. I have talked with men who have devoted their lives to iron and steel and they cannot account for it. The superintendent of the mills to whom this material was sold seemed to think that this crystallization was produced by vibration and that the reason why the bars showed more crystals at the heads than in the middle, was that the waves of vibration were more severe at the head than in the middle of the bar. As to the other question, I acknowledge I am not able to answer it.

Mr. J. B. Rohrer: I would like to ask Mr. Modjeski whether those eye bars were tested.

Mr. Modjeski: Not at the time. The intention was to make a full series of tests and at some future time I may be able to tell some results. Those bars were watched closely and some of the others were broken up and as far as learned they were all of the same character.

A Member: Have we any record of the manufacture of those bars?

Mr. Modjeski: I have not been able to learn how they were manufactured.

A Member: Is it steel or iron?

Mr. Modjeski: It is iron. At that time steel was not used in bridge building, in 1872.

Mr. Wm. M. Hughes: I would like to ask Mr. Modjeski why the span was not erected on the masonry protection instead of being erected on false work across the channel?

Mr. Modjeski: If the span had been put in on the protection there would have still been the old span to take care of and the change from the old span to the new might have consumed several days, thus causing interruption to traffic.

President Thos. T. Johnston: Speaking of the general question raised by Mr. Goldmark as to the character of movable bridges about Chicago, there is one problem presented in the city in connection with the sanitary district work that will be of some interest perhaps, and that is with reference to a movable bridge with eight parallel railroad tracks. The width of the bridge will be about 120 feet. If that bridge would turn around as a swing bridge, it would, when open, cover nearly the width of the stream to be spanned. I mention such a case as offering an interesting problem.

Mr. Modjeski: Mr. Goldmark's remarks suggest some further thoughts in regard to using wire rope for lift bridges. In our lift span they had to perform only a temporary duty, of course, and the question of maintenance was not considered. But at the end

of the period we perceived there was a considerable wear on the cables and I presume that another month would have worn them so that they would have become unfit for further use. I have heard that in lift spans the cables have been a great objection. I would like to hear from Mr. Goldmark on that point. The item of replacing cables in a lift span, I understand, is a very great one.

Mr. Goldmark: I think where the lift is small the expense for cables will not be excessive. I do not understand that it has been unduly great in the Syracuse bridge. At the same time, for moderate lifts some arrangement of gearing or of hydraulic machinery could probably be designed to take the place of cables. For very high lifts the cables will, of course, be very long and expensive, although our actual experience on the subject is limited to a very few examples.

Mr. B. B. Carter: There is one feature of the case that was not brought out in the paper that I think should be spoken of at least. I had the pleasure of being an interested witness to the operation at the time the change was made from the temporary structure to the permanent swing. To show the forethought that had been put into it by the engineers in charge, and also those in charge of the contract work, I would say that, in spite of the various gangs at work at the same time, in the different operations that were carried on simultaneously, there was not a hitch nor an accident of any character. If I recollect aright the plan was to have the draw span swing before 9 o'clock at night, and the first train (a freight train) passed over about half past five, showing that they were considerably ahead of time.

A Member: I would like to ask, if the stripping of the floor from the temporary span was a slow process, why did they do it?

Mr. Modjeski: Simply to reduce weight, besides, we did not know at one time whether we would not have to drop the span into the river if we could not lower it on to the boats.

Mr. J. C. Bley: I would like to ask, in looking the field over after the events had transpired, if it did not appear possible to have diverted the ice through the river-way from the draw span by cutting the ice away below and putting in timber work of any sort?

Mr. Modjeski: There are certain conditions where one is at a loss to know whether the disturbance will produce any good or harm. Especially in this case the ice was a uniform cake across the river practically and the river was rising rapidly; the ice was loose on the shore and if cut through in any manner might have broken up more quickly.

Mr. Geo. E. Thomas: I have had considerable experience with the breaking up of ice on the Missouri, the Mississippi and the Susquehanna rivers. While putting in bridge piers for Havre de Grace bridge, we drove an ice breaker of piles on up-stream end of piers, and connected them; the ice came down in such a volume that the weight of it was such as to sweep those piles out of existence.

At Glasgow, at the time I speak of, when the American Bridge Company lost the span, they had skiffs and steamboats up the river and tried by every means in their power to divert the danger, but all failed.

While on the engineering corps of the Illinois Central Railroad way back in the "70"s at Cairo, the ice came down there and I was sent down to take care of the inclines on which we used cradles for loading cars on to transfer boats. I had disconnected one cradle on the Kentucky shore across from Birds Point, Missouri, and had three boats—we had the H. S. Macomb, a very large transfer boat, to divert the ice at this point, but the ice came down and took the lower end of our cradle and we never saw it again. It is very easy to talk about stopping ice, but when there is big money at stake we feel that we have to be very careful.

MR. RALPH MODJESKI.

The reason given by me in the verbal discussion for erecting the draw span across the channel instead of on the masonry protection needs supplementing. Aside from the fact that the contract as executed by the U. S. Government permitted the contractors to erect the draw span across the channel, there were other conditions making it advisable to have it done in this precise manner. The possibility of a wash-out had been considered before the contract was let, also the resulting double loss. The loss of material and the interruption to traffic. The loss of material would be a loss to the contractors alone, who were willing to take the risk. The interruption to traffic would be a very serious loss to the railway interests, and the government endeavored to guard against it as far as possible. Had the new draw span been erected on the protection in the first place, the ice moving when it did would have carried away the falsework in the channel span, interrupting traffic for no shorter period than it has been interrupted. Not only that, but it would have been necessary to have the draw span erected complete before swinging, while in the manner which was attempted, one arm completed across the channel would have made things safe. (It was mentioned in the paper that the channel near the shore was comparatively safe.) This would have extended the time of danger by several days. Besides, it is doubtful if, when the day for turning the draw span came, the removal of the floor and falsework in both channels could have been accomplished in as short a time as has been employed in the removal of the lift span, and an interruption to traffic became then a necessity, accident or no accident, while it was the aim not to have any interruption at all.

The principal reason why the contractors adopted the method of erection across the channel was economy. It is much cheaper to use only one system of falsework and to use the same traveler to remove the old span and erect the new one. Of course, after the accident it became imperative to erect the new structure on the protection in order to leave the channel clear for navigation.

V.

DEEP WELL PUMPING.

By E. E. Johnson, Mem. W. S. E.

Read March 3d, 1897.

In recent years the increase in the population of the towns and villages of the United States and the consequent increasing difficulty in securing a supply of pure water for domestic use has turned the attention of engineers to the waters held by the sandstone formations. The great extent and uniform good quality of this supply are features that offset in a large degree the difficulty experienced in securing it.

The conditions of flow vary with the locality and the formations from which the water is drawn; the St. Peter and Potsdam sandstone sources in the Upper Mississippi valley being tapped at all depths up to about 1,500 feet from the surface and yielding flowing supplies in some cases, and non-flowing supplies in others; the depth of the water plane from the surface varying with the texture of the stone; the distance and head from the water-shed supplying the stratum, and the total demands made by the wells sunk. In any section the water plane is liable to change from the latter cause mainly, and in most instances goes down in proportion to the number of wells sunk in a given area. In the vicinity of Chicago the Potsdam wells flowed for a number of years subsequent to the first tapping of the stratum. The gradual lowering of the water plane has necessitated a change in the method of pumping, ordinary suction pumps attached to the wells giving a maximum relief to the water column of about 28 feet, and failing in many cases to secure the flow that can be supplied by the bore of the well.

Many devices have therefore been resorted to, in so relieving the water column as to secure all the water that can come up through the bore hole. Cylinders placed from 50 to 500 feet below the surface are mostly relied on to do the work.

The purpose of this paper is to discuss from an engineering and a practical standpoint the various types and kinds of pumping machinery applied to this service.

The prime mover is the cylinder which has few variations from type. Ordinarily it is of seamless drawn brass tubing with a check valve in the bottom, and having a valved plunger. Poppet valves are sometimes used, but more commonly brass balls in

both plunger and check, Figure 89, are found to resist shock and wear better.

The plunger is packed with three or four cup leather rings. All valves are, or should be, so arranged as to be easily withdrawn from the well. The cylinder is suspended from the surface by a

Fig. 88.

Fig. 89.

drop pipe of slightly larger diameter than its bore, or, if the well is cased with iron tubing, may be locked into the casing by an expansible packing of rubber assisted by steel dogs to grip it fast. Such a cylinder uses the well casing for its discharge pipe. The cylinders named must obviously be single acting, so as to keep the plunger rods in tension, as otherwise excessive buckling would

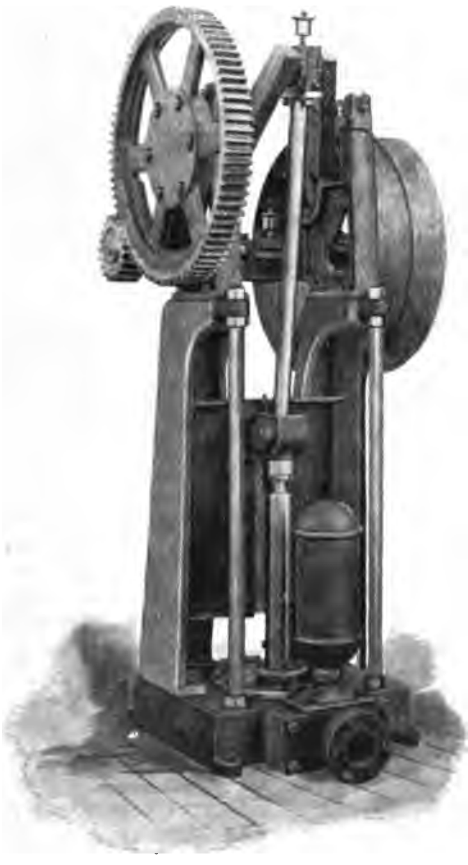


Fig. 90.

soon ruin the rod. Double acting cylinders have been made and used to a slight extent, but not for very high lifts, on account of the buckling of the rod.

The plunger rod is commonly made of ash in lengths of about 20 feet, coupled with a straight threaded joint, furnished with a heavy shoulder to butt against. Iron pipe with long hydraulic couplings is sometimes used instead.

In using a single acting cylinder the discharge must manifestly take place on the up stroke only, except in cases where the discharge lift above the pump allows the use of a differential plunger at the pump head, of half the plunger area. This, to some extent, equalizes the work of the up and return strokes.

Double acting cylinders having two plungers working one above another, and connected to a solid and a tubular rod are used with special types of working heads, and will be noticed farther on; these keep the rods always in tension.

The motive power is commonly steam used in a simple form of direct acting engine placed tandem with the pump cylinder. (Fig. 88.) It uses steam non-expansively, an indicator card from one being a rectangle with an admission line high enough to carry the plunger load. All exhaust openings are provided with throttle valves to cushion the piston with. As a matter of fact these valves perform a very important function. By the law of the conservation of energy we should look for the prompt restoration to the water column on decreasing its velocity, of the energy stored in it by virtue of its momentum, and true to its law, this action does take place, incidentally causing a savage water-hammer, to overcome which the motion of the steam piston is carefully guarded.

The limit of speed in pumps of this class is determined largely by the number of reversals per minute which the motion of the plunger can make without excessive shock to the machinery—25 full double strokes per minute being the practical maximum.

Geared Pumping Heads, Fig. 90, taking power by belt are also used and offer a more economical means of raising water than the direct steam heads, the pumping cost varying with the kind of driving motor used. For deep lifts a double acting geared head has been used successfully, and with fair economy.

The air lift consisting of an air compressor, an air reservoir, and an air pipe in the well carried down from the surface about double the depth of the water lift is in somewhat common use. This machine is called the "Pohle" lift after its American inventor, but was first used about twenty years ago by Dr. Werner von Siemens for mine drainage. This method of pumping has some advantages in the way of simplicity of the mechanism employed, and where the lift is comparatively low and the question of economy does not enter it is useful.

As the subject of pumping by compressed air is somewhat lacking in data it may be profitable to examine it carefully. The first element is the air compressor, which is commonly of the single cylinder straight line type, having its steam and air cylinders placed tandem, the steam end being furnished with a cut-off valve of some description; the difference between the energy applied and absorbed being stored in heavy fly wheels. Duplex single stage compressors are sometimes used and occasionally two stage machines.

The main sources of loss of energy in compressors may be summarized and given value approximately according to the following

Fig. 91.

TABLE OF HORSE POWER REQUIRED
TO LIFT ONE CUBIC FOOT OF WATER PER MINUTE FROM ANY DEPTH TO 300 FT.

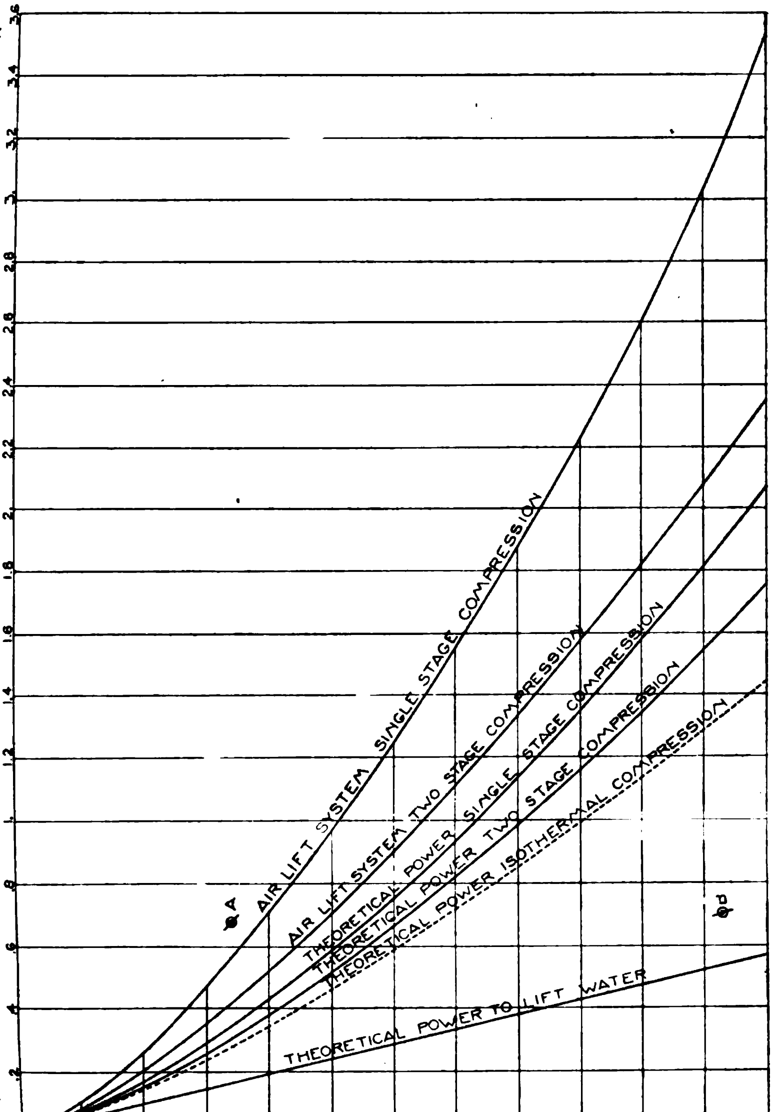


TABLE IV.

Losses by	Pounds gauge. Approximate.				
	14.7	43	73.5	103	135
	Atmospheres pressure.				
	2	4	6	8	10
Machine friction	28	13	8	5	04
Heating air in entering......	5	8	10	12	15
Heating air in compression..	11	20	24	27	30
Clearance and valves.......	1	2	3	4	5
Total loss	45	43	45	48	54
Machine efficiency..........	55	57	55	52	46

The losses are expressed as percentages of the total work of the compressor and are based on the following assumptions:

Machine friction is assumed as 8 per cent when compressing to six atmospheres, and unvarying in amount under the pressures named; the percentage varying manifestly with the total load.

The heating of the air in entering by heat taken from the walls of the admission passages is based on an increase of initial temperature of the air from 60° to a temperature proportionate to the temperature of the cylinder walls in partially cooled compression when the exponent of the compression curve is 1.25. The heating during compression is due to imperfect means of getting rid of the heat of compression, and is based on the loss due to adiabatic compression, where the exponent of the compression curve is 1.4; the work wasted being calculated in foot-pounds, and the total compared to the energy theoretically required for isothermal compression.

Clearance and valve losses are based on 3 per cent of clearance, and appear as a loss of volume, the longer cylinder and its increased friction being required for a given output. This loss varying with final pressure reached in the cylinder.

The problem as thus far stated is concerned with the delivery of the air to the storage reservoir, and from the tabulated efficiencies it will be seen that the cost of compression does not vary considerably for pressures up to eight atmospheres or about 100 pounds gauge. The storage of the air is a matter of convenience only, and does not affect the efficiency of the plant. It affords the air an opportunity to cool down to the temperature of the surrounding air, and before it is allowed to expand in the discharge pipe of the well it is further cooled to the temperature of the water.

So far the problem can be analyzed as shown on the accompanying diagram Figure 91, which shows graphically the theoretical amount of power required to raise one gallon of water per minute from any depth down to 300 feet; the theoretical power required to compress the necessary air adiabatically when ex-

panded isothermally as in this case it is; the actual power required to deliver the theoretical quantity of air assuming the compressor losses, aside from heating during compression, to be 22 per cent of the power applied; also the actual horse power required to deliver one cubic foot of water per minute from any depth, assuming the efficiency of the air lift itself to be 100 per cent, which is too high an efficiency to be made good in any case. The experiments of Browne and Behr showing 50 per cent efficiency in one experiment only out of 33 recorded, and that with a submersion of .6 of the lift and a velocity of discharge of less than four feet per sec.* Data on this phase of the subject is meagre; the results of the Rockford, Ill., tests showing 38 per cent efficiency for the air lift only at 85 feet lift.

The following tables V and VI of well depths, and weir readings, and computed horse power of compressor taken during a 24 hour test of the air lift system at Rockford, Ill., are interesting testimony. The system is applied to four St. Peters wells. Power is supplied by a 14″×22″ duplex air compressor taking steam from the waterworks pumping station boilers. No arrangement was made for securing a coal test. Data, in addition to the steam and air cards shown in Figure 92 and 93, are as follows:

Width of weir in feet 2.52′.
Average head pumped against 85.125 feet.
Formula for weir discharge,

per $Q = 3\frac{1}{3}\,(L\ \frac{1}{10}\ N.\ H.)\ H.^{\frac{3}{2}}$

Q = cubic feet per sec.,
N = number of end contractions, taken as 2,
H = weir reading in feet,
L = length of weir in feet.

The discharge from the weir at time the air card was taken was 1,392 gallons per min., which calls for the expenditure of 30 H.P. to deliver.

The analysis of the steam card shows nothing worthy of especial comment, except late admission.

The air card shows much that is interesting. The compression line on one card is accompanied for purposes of comparison by the isothermal and adiabatic curves. It is evident that the air piston worked without much leakage. The compression curve, it will be observed, follows the adiabatic very closely, showing that water jacketing on air cylinder does not accomplish much in reducing the power expenditure of compression in a single cylinder, owing to the fact that the air has little time to part with its heat, and the jacket is covered up by the advancing piston so that little of it can be effective when most needed; its office being largely to keep down the excessive cylinder temperature that would heat the incoming air and destroy the lubrication. The

*Transactions of the Technical Society of the Pacific Coast, Vol. VII, February, 1890.

TABLE V.

TWENTY-FOUR HOUR TEST OF THE FOUR (4) ST. PETER WELLS, ROCKFORD, ILL.

Date.	Hour.	Rev. of Comp.	Air Press.	Steam Press.	Distance from Top of Ground to Water. Well No. 1.	Well No. 2.	Well No. 3.	Well No. 4.	Weir Rg.	Est. Flow.	Galls. per 24 Hrs.
Feb. 6, '96	1:15 P. M.	99	79	84	81	81.5	79.5	59.0.	.534'	......	....
" 6, "	2:15 "	98	77½	81	82	83.0	80.5	59.0	.5285'	......	....
" 6, "	3:15 "	100	77	77	83.5	84.0	82.5	59.0	.5320'	......	....
" 6, "	4:15 "	100	76½	76	84.	84.5	82.5	59.0	.5305'	......	....
" 6, "	5:15 "	99	76½	82	84.	84.0	82.5	59.0	.5305'	......	....
" 6, "	6:15 "	100	76	81	84.	84.5	82.5	59.0	.5345'	......	....
" 6, "	7:15 "	...	..	..	83.5	84.0	82.5	59.0	.534'	......	....
" 6, "	8:15 "	100	76½	..	83.0	84.5	82.5	59.0	.5335'	......	....
" 6, "	9:15 "	100	76½	80	84.	84.5	83.0	59.0	.533'	......	....
" 6, "	10:15 "	100	76	82	84.	84.0	83.0	59.0	.5335'	......	....
" 6, "	11:15 "	99	76	80	83.5	84.0	82.5	59.0	.5345'	......	....
" 7, "	12:15 A. M.	97	76	78	84.	85.0	82.5	59.0	.532'	......	....
" 7, "	1:15 "	96	76	81	84.	84.5	82.5	59.0	.532'	......	....
" 7, "	2:15 "	95	76	82	84.	84.5	82.5	59.0	.532'	......	....
" 7, "	3:15 "	95	76	82	84.5	84.5	82.5	59.0	.532'	......	....
" 7, "	4:15 "	93	76½	81	85.0	85.0	83.0	59.0	.529'	......	....
" 7, "	5:15 "	95	76½	81½	84.5	84.5	83.0	59.0	.530'	......	....
" 7, "	6:15 "	95	76	81	84.0	84.5	82.5	59.0	.535'	......	....
" 7, "	7:15 "	95	76	81	83.5	85.0	82.5	59.0	.5315'	......	....
" 7, "	8 "	..	..	..	83.0	84.5	82.5	59.0	......	......	....
" 7, "	9:15 "	..	..	..	84.0	84.5	82.5	59.0	.5303'	......	....
" 7, "	10:15 "	96	76	81½	84.5	84.5	82.5	59.0	.529'	......	....
" 7, "	11:15 "	95	76	79	85.0	85.0	83.0	59.0	.531'	......	....
" 7, "	12:15 P. M.	95	76	81	85.0	85.0	82.5	59.0	.532'	......	....
" 7, "	1:15 "	95	76	81	83.5	85.0	83.0	59.0	.532'	......	....
" 7, "	2.15 "	95	76	81	84.5	85.0	83.0	59.0	.529'	......	....

REMARKS.—From top of ground to discharge, 7.5'; width of Weir, 2.52'. Weir readings are average of highest and lowest readings.

TABLE VI.

INDICATOR CARDS ON THE 14×22 DUPLEX AIR COMPRESSOR, TAKEN DURING TWENTY-FOUR HOUR TEST OF THE FOUR ST. PETER WELLS, ROCKFORD, ILL.

Date.	Hour.	No. Revolutions.	Air Pressure.	Steam Pressure.	L. H. or R. H. Side of Engine.	Air or Steam Cylinder.	M. E. P. Head End Cylinder.	M. E. P. Crank End.	H. P Head End.	H. P. Crank End.
Feb. 6, '96	4.00	98	77	77	L. H.	Air.	37.60	34.65	63.00	58.08
" 6, "	5.00	98	77	76	"	Steam.	39.78	37.83	66.67	63.40
" 6, "	5.08	100	76	83	"	"	40.86	38.83	69.88	66.37
" 6, "	5.35	100	76	83	"	Air.	37.01	33.91	63.29	57.99
" 6, "	5.44	100	77	83	"	"	37.70	34.26	64.47	58.59
" 6, "	5.50	98	76	82	"	"	36.84	34.22	61.75	57.38
" 7, "	8.45	94	77	82	"	"	36.82	33.86	59.19	54.43
" 7, "	9.15	97	76	83	"	"	36.52	34.56	60.58	57.33
" 7, "	1.35	96	76	82	R. H.	"	34.37	33.58	56.43	55.12
" 7, "	1.40	96	76	81	"	"	34.65	34.33	56.88	56.36
" 7, "	1.43	96	76	82	"	"	35.13	34.31	57.67	56.32
" 7, "	1.45	96	76	82	"	"	34.40	33.76	56.47	55.42
" 7, "	1.48	96	76	82	"	"	34.42	33.61	56.51	55.19
" 7, "	2.08	91	76	78	"	Steam.	37.89	37.89	58.97	58.97
" 7, "	2.12	95	76	80	"	"	38.21	38.32	62.08	62.25
" 7, "	2.15	95	76	81	"	"	38.53	38.23	62.60	62.11
" 7, "	2.31	91	76	79	"	"	37.80	37.38	58.82	58.17
" 7, "	2.38	96	76	83	"	"	38.74	38.84	63.60	63.77
" 7, "	2.42	98	76	80	"	"	38.63	34.60	64.74	63.02
" 7, "	3.00	96	76	80	"	Air.	35.01	34.64	57.48	56.88

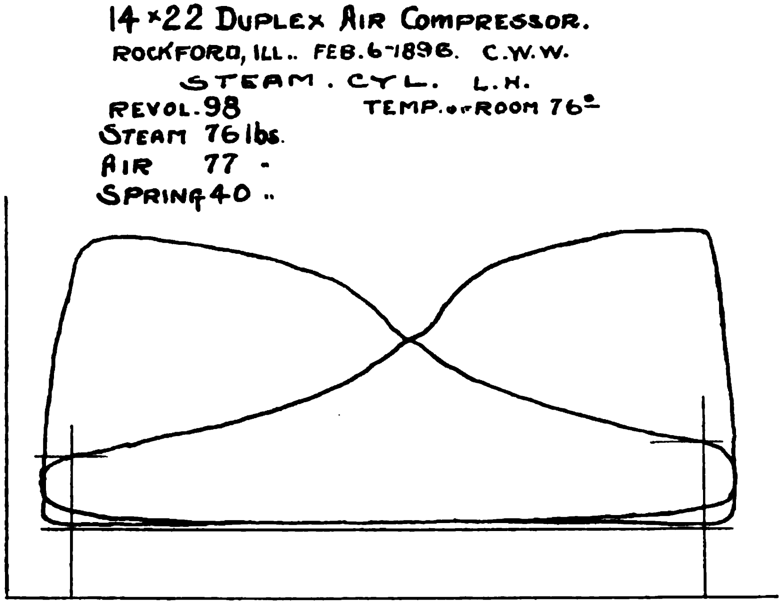


Fig. 92.

isothermal or least-work air card is outlined by hatching, and by comparison it will be seen that considerable power is wasted in operating the discharge valves.

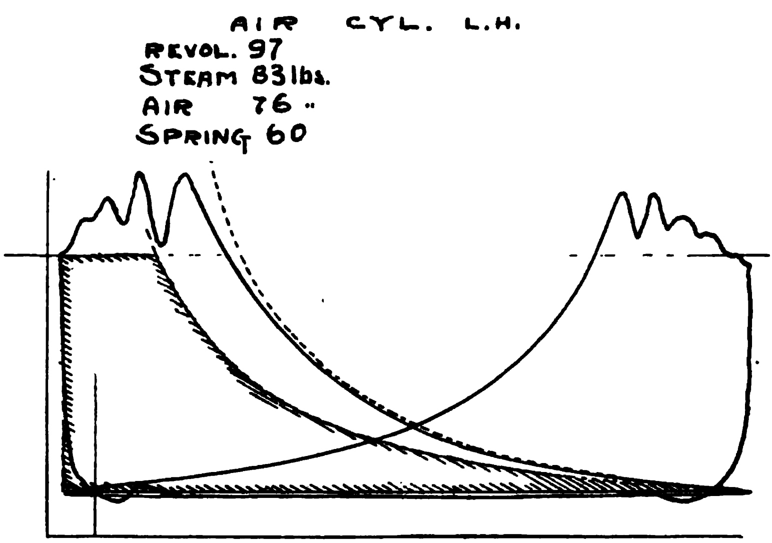


Fig. 93.

The clearance also shows a decided loss of cylinder volume by re-expansion behind the piston. The admission line shows that the valve springs used were strong enough to cause a considerable drag on the piston throughout the stroke.

The results of the tests may be analyzed as follows:

Horse Power to steam end of compressor	125.4
Horse Power to air end of compressor	117.6
Horse Power from air end of compressor, theoretical	85.6
Horse Power from air end of compressor, actual	79.5
Horse Power from wells	30.0

Machine efficiency of compressor.. $\left\{ \frac{117.6}{125.4} \right\} = 93.75$ per cent.

Total efficiency of compressor from steam supplied to air delivered... $\left\{ \frac{79.5}{125.4} \right\} = 63$ per cent.

Efficiency of Pohle lift from air supplied to water delivered.......... $\left\{ \frac{30}{79.5} \right\} = 38$ per cent.

Total efficiency of the plant from power supplied to water delivered $\left\{ \frac{30}{125.4} \right\} = 24$ per cent.

Unfortunately the test is wholly lacking in data on which to figure a duty; but assuming a steam consumption of 50 pounds per H. P. per hour, which from the character of the plant is not far wrong, a duty of 9.4 million foot-pounds per 1,000 pounds of steam was secured.

Taking up the subject of deep well pumps having cylinders, plungers and rods, we will examine first the practical operating conditions.

It is necessary to have a minimum of parts of sufficient strength to withstand the service, and to maintain the working conditions so as to give the longest service with the least expense.

The column of water between the cylinder and the surface can obviously be acted on by the plungers only, and passing the single acting cylinder with its one plunger as not being adapted to large work, we will consider the action of the pump column when moved by two plungers.

In Figure 94 is shown graphically the motion of a pair of plungers operated by cranks 180° apart, and provided with connecting rods 7½ cranks long. The vertical distance representing velocity of the plunger and the horizontal distance representing time. Obviously any vertical ordinate represents the velocity of discharge at the instant. The cross hatched portion above datum represents the discharge stroke and the dotted lower portion the

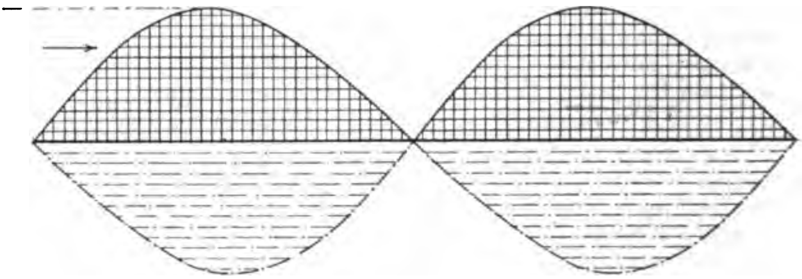


Fig. 94.

suction stroke. It is clear that twice in each revolution of the pump the water column is brought to a maximum velocity and twice stopped still. Theoretically considered the energy stored is restored so that no loss ensues, and this is true, but in practice the restoration takes place so rapidly and with such inconvenient force as to render it an exceedingly difficult problem to design machinery to withstand the blows inflicted by the water hammer, and the strains incident to overcoming the inertia of the column twice in every revolution. This fact has always limited the speed and capacity of this class of pumps.

In table X are shown the pressures on the cross head pins for a pump of this class, moving a water column weighing 4,200 lbs., approximately, the capacity of a 7-inch pipe 250 feet long, the cranks being 12 inches long, and revolving 30 times per minute, the observations being taken every 10° during the stroke; the minus sign before a number indicating the addition of

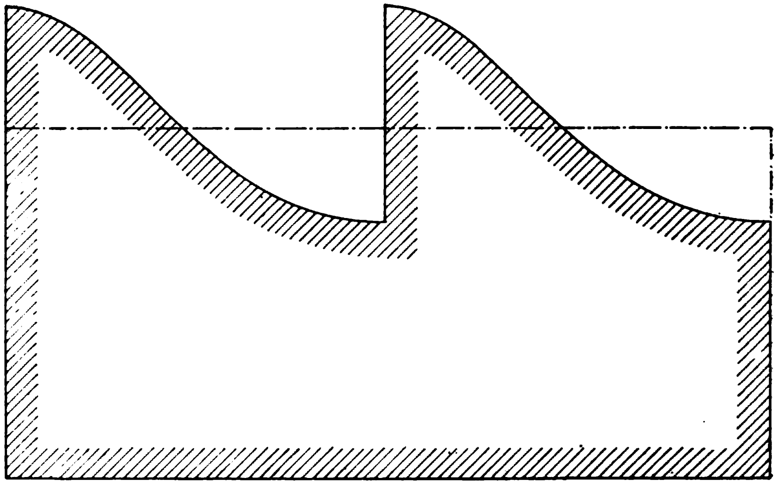


Fig. 95.

the amount, and the plus sign the subtraction of the amount to or from the dead load of 4,200 lbs.

During the first half of the up stroke the acceleration adds to the plunger load, and during the last half it assists by virtue of the momentum of the water column, thus lessening the load on the cross head pins.

The result of the tabulation is shown graphically in Figure 95, the vertical ordinates representing the net load at the cross head at any point in the stroke. It will be seen the load changes instantly from 3,072 lbs. to 5,670 lbs., an increase of 85 per cent. It is this cycle of operations repeated twice for every revolution, in addition to the resulting water hammer, that proves so discouraging to iron and steel, and incidentally to designers of this class of pumps.

Below are tabulated two tests made on a pump of this kind, Figure 96, at DeKalb, Ill., from which the principal deductions (see Table VII) are as follows:

Pump running 22.75 revolutions per minute.

Theoretical capacity in gallons per minute.......	178.2	
Actual " " " " "	141.2	
Slip of valves....................................	20.2	per cent
Horse power to electric motor..................	9.85	
" " from " "	7.30	
" " " pump.........................	4.13	
Efficiency of motor $\left\{\frac{7.3}{9.85}\right\}$	74	per cent
" " pump $\left\{\frac{4.13}{7.3}\right\}$	56	per cent
" " motor and pump $\left\{\frac{4.13}{9.85}\right\}$	42	per cent

See Table VIII.

Pump running 33 revolutions per minute.

Theoretical capacity in gallons per minute........	258.4	
Actual " " " " "	234.8	
Slip of valves....................................	9.2	per cent
Horse power to electric motor..................	14.4	
" " from " "	11.68	
" " " pump.........................	7.86	

Efficiency of motor $\left\{\frac{11.68}{14.4}\right\}$ .... 81 per cent

" " pump $\left\{\frac{7.86}{11.68}\right\}$ .... 62 per cent

" " motor and pump $\left\{\frac{7.68}{14.4}\right\}$ .... 54 per cent

Motor Test.

NO LOAD.

Volts 220, Amperes 8.25=1815 Watts—Armature Resistance Loss 1 Volt for 10 Am.

CONDITIONS.

Bottom of pump cylinder below floor of pump house...	161 ft.
Bottom of air gauge pipe " " " " " ...	146.54 "
Surface of water in well " " " " " ...	76.66 "
Diameter of pump cylinder..........................	8 in.
Stroke, each valve 18 in.—Revolution.................	36 in.

TABLE VII.

TEST WITH PUMP AT SLOW SPEED.

Time.	Volts.	Amperes.	Well Gauge.	Revolutions.
3.50	*222	32	15.5	....
3.55	218	33	15.5	....
4.00	222	32	15.5	....
4.05	220	33	15	....
4.10	219	34	14.5	....
4.15	220	33	14.5	....
4.20	223	33	13.5	....
4.25	223	33	13.5	....
4.30	224	33	13.5	....
4.35	223	34	13.5	....
4.40	222	34	13.5	....
4.45	221	34	13.5	....
4.50	221	34	13.5	1365.
Av'ge	221.4	33.2	14.2	22.75

Power = 7350.5 watts—1898 watts = 5451.5 at belt.

Water in well below floor, 113.74 feet.

Water in reservoir above floor, 3 feet.

Lift total, 116.74 feet.

*Water pumped into reservoir, 71,109 pounds.

* One cu. ft. of water taken at 62.35 lbs.

TABLE VIII.

TEST WITH PUMP AT FAST SPEED.

Time.	Volts.	Amperes.	Well Gauge.	Revolutions.
2.15	216	49	7	....
2.20	218	48	6.5	....
2.25	214	49	6.5	....
2.30	216	50	6.5	....
2.35	216	49	6.5	....
2.40	216	50	6	....
2.45	213	50	6	....
2.50	214	51	6	....
2.55	213	50	5.5	....
3.00	214	51	5.5	....
3.05	214	51	5.5	....
3.10	214	51	5	....
3.15	214	51	5	1980
Av'ge	214.8	50	6	33

Power delivered to pump 10740 – 2024 = 8716 watts.

Lift total, 132.7 feet.

Water pumped into reservoir, 117,427 pounds.

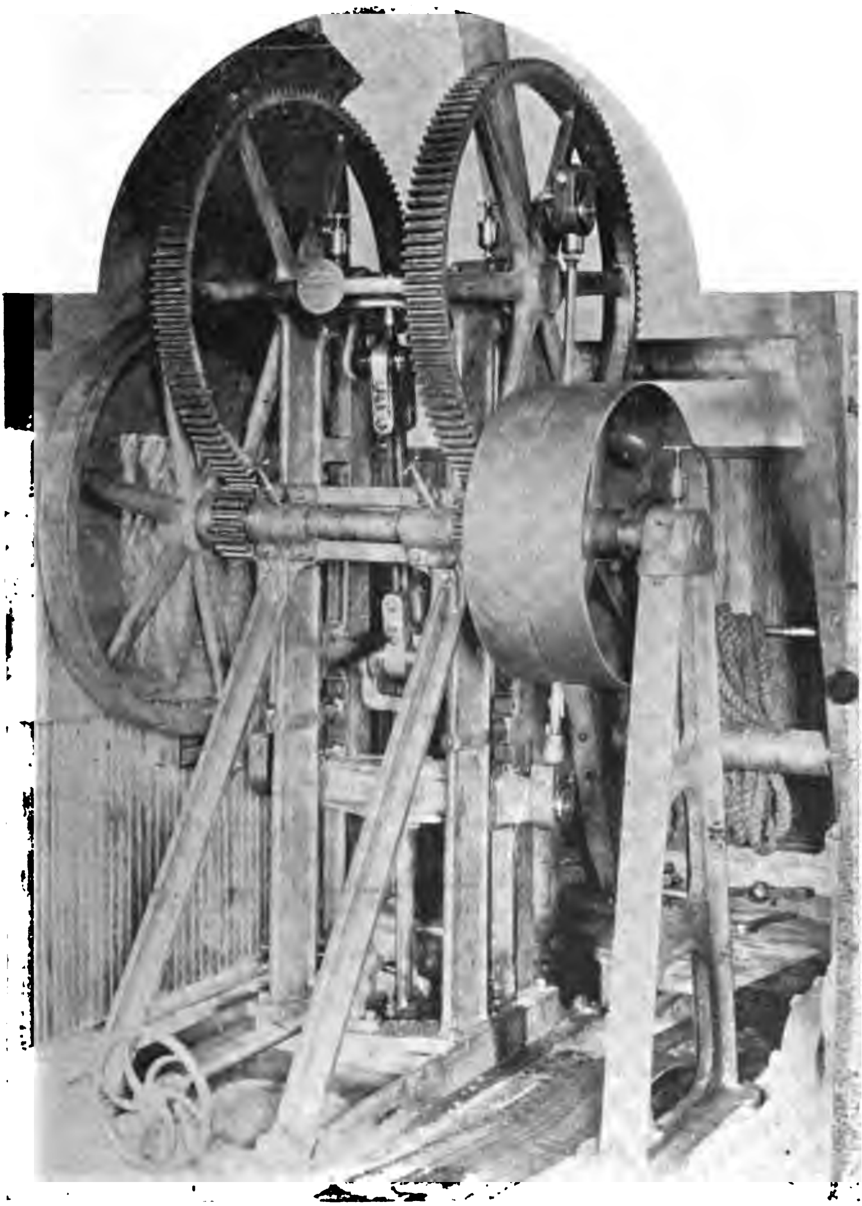


Fig. 96.

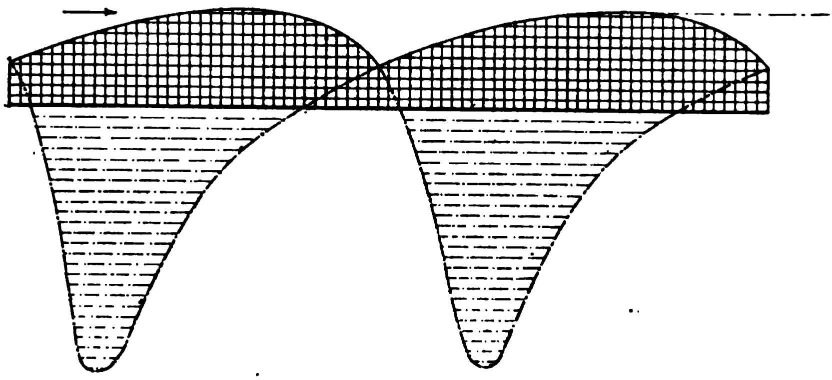


Fig. 97.

It will be clearly seen from the diagrams and tabulations given above that under ordinary conditions of operation, the intermittent action of double acting pumps on the water column is not all that could be desired, when the quantities required are large and the lifts high; this, and the manifest inability of the air lift to cope economically with the same conditions, led the writer to design a pump overcoming the difficulties shown to exist in the other types.

Two plungers are employed whose motions are shown in diagram in Fig. 97 drawn to a scale, and for working conditions similar to Fig. 94. It will be seen from an inspection of the diagram that the water column never stops, its minimum velocity being about half its maximum—in practice probably considerably more than half. The maximum velocity being 75 per cent of that necessary for an ordinary double acting pump.

The velocity of the downward or idle stroke of the plunger is

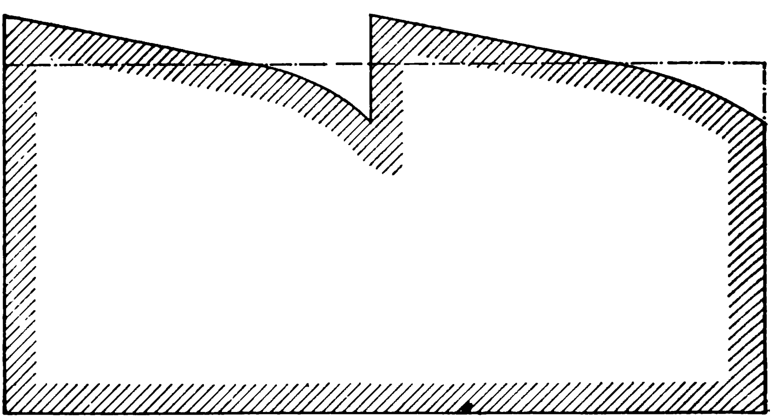


Fig. 98.

much greater, being effected in 69 per cent of the time occupied by the up or working stroke of the same plunger. Time is thus secured by arranging the strokes to allow both plungers to move upward simultaneously, one at an increasing and the other at a decreasing rate of speed, the load of the water column being changed from one to the other when the speed rates are equal.

By the means shown, shock to the machinery coming from the change in plunger load is largely avoided, and the serious element of water hammer is entirely eliminated. The ideal mechanism would raise the water column at an unvarying rate of speed, and therefore without acceleration.

In Fig. 99 is shown graphically the line of no acceleration, and also the actual line of acceleration produced by the pump. It will be observed that the plungers start upward more slowly than the average rate, and gradually increase to the end of the stroke.

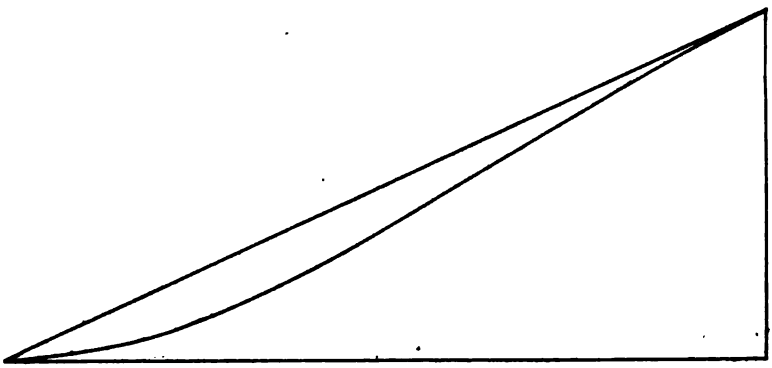


Fig. 99.

Contrasting this with Figure 100 for the common type of double acting plunger, it will be seen the departure from the line of no acceleration is less wide and abrupt. The net plunger loads are shown in Figure 98, based on a load of 4,200 pounds as before, the maximum pressure at the cross head being 4,766 pounds and minimum 3,456 pounds, giving a variation of 38 per cent. in the load as compared with 85 per cent. in the old type of pump (Fig. 95).

In practice the results bear out fully the expectations of quiet working on which the design was based; one severe test successfully withstood consisted in operating the pump for several hours at a speed of 200 gallons per minute under a 250 ft. head, when the well furnished but 73 gallons per minute. Under ordinary conditions serious water hammer would have resulted, which, in this instance, was not manifest in any degree. Owing to the failure of the well to give the pump its capacity as already noted, any tests for efficiency must show the pump seriously handicapped, as the friction load from the mechanism of both pump and driv-

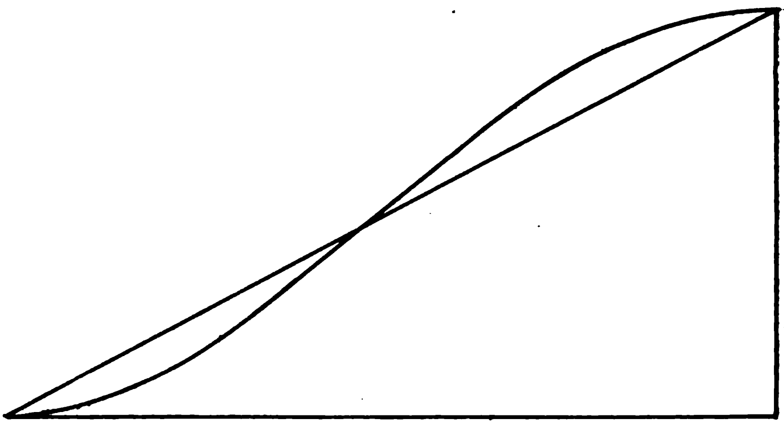


Fig. 100.

ing engine is a much larger factor of the total work than they would be were the plant working normally.

In order to determine the capacity of the pump under the terms of the contract, the consulting engineer had a sufficient supply of water put in from a separate source at the top of the well, and the pump gave its full rated volume without shock or water hammer. It was impossible, however, to ascertain the head pumped against, and therefore no test of power was attempted.

With the explanation as noted the following test is appended.

The plant consists of a 36 H. P. Otto Gasoline Engine driving two pumps; a duplex double acting power pump of 300 gallons perminute capacity used for fire service or to pump from the

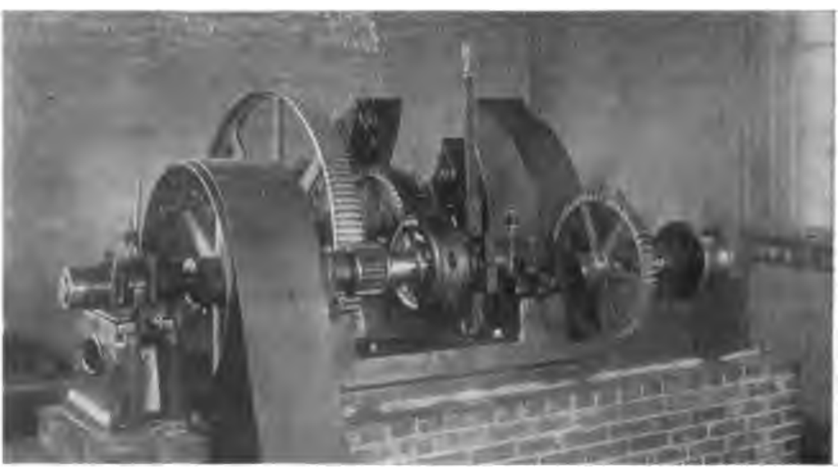


Fig. 101.

surface reservoir to the stand-pipe, and the deep well pump (Fig. 101).

Both pumps are connected to the engine by 10-inch double leather belts with 15-ft. belt centers. In the test for engine efficiency both belts were being driven, and their losses are included with the engine load, and it was a difficult task to remove the belts.

Data of Test.

Pump lift in feet	252
Cylinder diameter in inches	6¾
Pump stroke per revolution in inches	41.25
Pump capacity per revolution, gallons	6.39
Duration of test	1 hour
Revolutions of pump per minute	11.62
Capacity of pump per minute, gallons	74.24
Water pumped per minute, reservoir measurement, gallons	71.82
Slip of valves	3 3-10 per cent
Speed of gasoline engine per minute	220
Value of one explosion in horse power (from card Figure 15)	.425
Explosions per minute, pump running	30
Explosions per minute, pump not running	14
Explosions per minute to run pump	16
Horse power to pump	6.8
" " from "	4.56
Efficiency of pump	67 per cent
Total horse power developed in engine	12.75
Horse power to run engine and two belts	5.95
Efficiency of whole plant from power applied to water delivered	36½ per cent

From the data presented it will be seen that, in spite of all unfavorable conditions, the new type of pump gives a good account of itself. It was fully expected that further data would be available at this time, but various delays have made it impossible to secure it.

The cost of pumping, exclusive of attendance in various plants, is shown in Table IX, in so far as it could be secured.

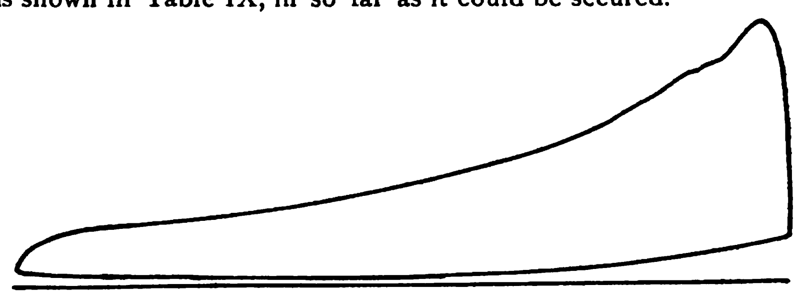


Fig. 102.

TABLE IX.

Place.	Pump Size		Capacity Gallons per Min.		Slip %	Lift in Feet	Horse Power		Machine Efficiency		Fuel Consumed per H. P. Hour from Pump		Watts per H. P. from Pump
	Diam.	Stroke	Theoretical	Actual.			To Pump	From Pump	Pump only %	Whole Plant %	Coal lbs.	Gasoline 74 % Gallons	
Galva, Ill.	6¼ in.	Double 24 in.	192	58.8	69.2	300		4.32			42.		
Aledo, Ill.	5¾ in.	Single 34 in.	99.4	80.	1 9.5	160		3.3			74.6		
De Kalb, Ill.	8 in.	Double 18 in.	178.2	142.1	20.2	116.74	7.31	4.13	56.4	42.			1776.
Ditto.	Ditto.	Ditto.	258.4	234.8	9.2	132.7	11.68	7 86	62.3	54.6			1366.
Rockford, Ill.	Air	Lift.		1392		85.125	79.5	30.	37.9	24.			
Cambridge, Ill.	6¾ in.	Double 20⅝ in.	74.24	71.82	3.3	252	6.8	4.56	67.	36.5		.215	

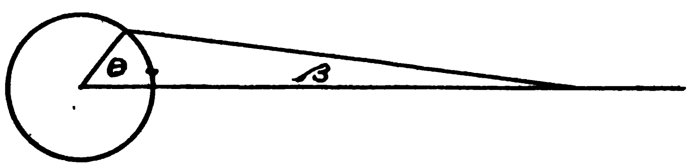
TABLE X.

Formulae:—

$$\text{Acceleration} = -a\,w^2 \left\{ \left(\cos\Theta + \frac{a\left[b^2(1-2\,\text{Sine}^2\Theta) + a^2\,\text{Sine}^4\Theta\right]}{(b^2 - a^2\,\text{Sine}^2\Theta)^{\frac{3}{2}}}\right. \right\}$$

w = velocity of a point in the crank one foot from center of shaft,
a = length of crank,
b = length of connecting rod.

Point.	Θ	β	Distance of Plunger from Bottom.	Velocity of Plunger in Ft. per Sec.	Accel. of Plunger in Ft. per Sec.	Pressure to produce Acceleration in 4200. lbs.
0	0°	0°	.0 ft.	.0	— 11.18	— 1470.
1	10	1°–25	.02	.6	— 10.85	— 1430.
2	20	2–37	.06	1.20	— 10.25	— 1350.
3	30	3–50	.15	1.73	— 9.16	— 1206.
4	40	4–57	.26	2.20	— 7.76	— 1025.
5	50	5–52	.40	2.61	— 6.10	— 805.
6	60	6–45	.55	2.84	— 4.37	— 576.
7	70	7–12	.80	3.08	— 2.38	— 314.
8	80	7–33	.88	3.14	— .49	— 59.
9	90	7–40	1.06	3.14	+ 1.39	+ 170.
10	100	7–33	1.23	2.98	+ 2.33	+ 308.
11	110	7–12	1.32	2.79	+ 4.35	+ 575.
12	120	6–45	1.52	2.51	+ 5.55	+ 733.
13	130	5–52	1.71	2.20	+ 6.50	+ 857.
14	140	4–57	1.80	1.82	+ 7.33	+ 965.
15	150	3–50	1.89	1.38	+ 7.88	+ 1040.
16	160	2–37	1.94	.94	+ 8.24	+ 1085.
17	170	1–20	1.98	.49	+ 8.46	+ 1115.
18	180	0–0	2.00	.0	+ 8.55	+ 1128.



The thanks of the writer are specially due to C. C. Stowell D. W. Mead, J. W. Glidden, L. B. Merriam, C. V. Dickinson Robert Candor, Eugene Palmer and others for courtesies extended and data furnished.

DISCUSSION.

Discussion by THOS. T. JOHNSTON, President W. S. E.

Mr. E. E. Johnson has discussed, with great ability, certain phases of pumping machinery as applied to pumping water from deep wells. He has exposed the economy of the old-fashioned deep well pump and of the application of compressed air as used by the Pohle Air Lift. He has, further, described a new deep well pump which he has invented and in which are eliminated sources of extraneous resistance existing in former types, with the result that his machine will develop a higher economy and capacity than anything of the kind hitherto attempted. He is to be particularly congratulated upon the happy way in which he has set forth the economy, or lack of economy, of the Pohle Air Lift and older forms of pumps.

He has, however, omitted any reference whatever to a method of pumping from deep wells which has had application in a number of important cases, with good results. It will be well, before discussing this method, to arrive at a more explicit description of a deep well, a thing Mr. Johnson has assumed to be understood.

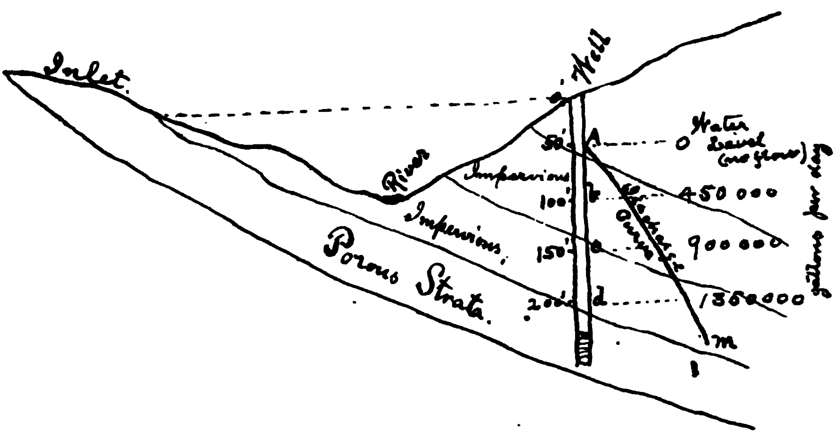


FIG. 103.

Fig. 103 illustrates a deep well, the water passing from the part marked "Inlet" by way of the porous strata to the well, in which it rises to the level "A." It cannot rise higher because by doing so it would rise above its source. This is not a case of a flowing well, but for reasons that will appear further on it may be a well

THOMAS T. JOHNSTON, PRESIDENT W. S. E.—1897.

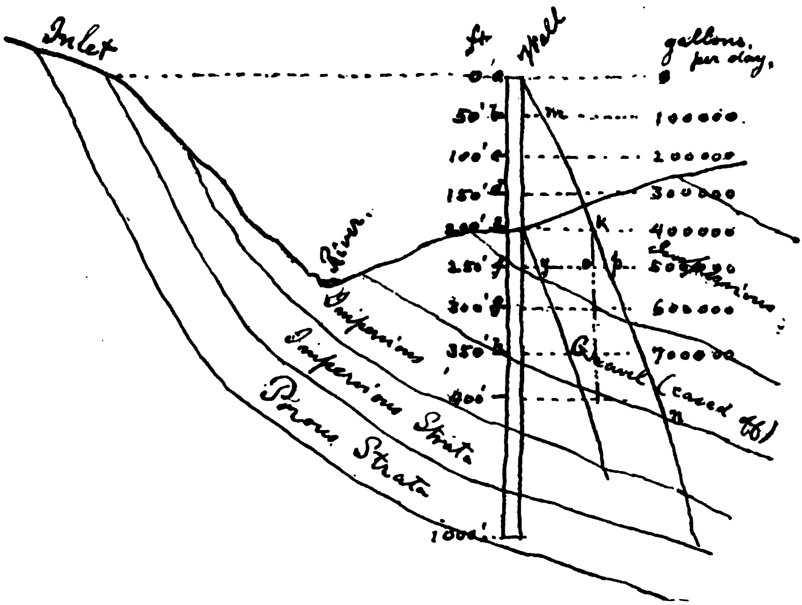


FIG. 104.

that can be made to yield water abundantly. Fig. 104 illustrates a deep well, the water passing as before from "Inlet" by way of porous strata to the well and will be flowing well unless the well tube be carried above the surface of the ground to the level "a," above which level it cannot rise without rising above its source.

Suppose, in Fig. 104, the well tube be carried to the level "b." Manifestly, water must flow over the top of the tube. For the sake of illustration assume this flow to be at the rate of 100,000 gallons per day, and the distance "ab" to be 50 feet. Again, suppose the well tube terminates at the level "c," the distance "bc" being 50 feet. Will the flow over the top of the tube differ from what it was when the tube terminated at "b"? Curiously enough, when asked this question, many people who should know better have doubts as to whether to give a positive or negative answer. Their hydraulic sense seems to go no further as will be illustrated by an example or two to be cited below. The flow will certainly be increased, it being assumed here and elsewhere in this discussion that the quantity of water derived from the well is not in excess of what will permanently come to the well from the "Inlet" and porous strata. Why should the quantity be greater? When the flow was taking place at the level "b" frictional resistance to flow was existing at all places between the "Inlet" and top of the tube where the water was in motion, and the velocity of that flow was necessarily limited to such an extent that the head needed

to overcome the resistance was just equal to the distance "ab," or 50 ft. "ab" was the head that caused the flow. Now with the flow taking place at the level "c," instead of "b," the head called into action to create flow is "ac," equal to 100 feet. In order that this head may be used up there must be greater resistance to flow and this can only happen when there are higher velocities than when flow was taking place at "b." Higher velocities must necessarily result in larger flow. Therefore, with the well tube cut off at "c" more water will flow than if cut off at "b." As before, for the sake of illustration, this flow may be assumed to be 200,000 gallons per day.*

Suppose, now, the well tube be cut off successively at "d" and "e." The flow will be still further increased in accordance with the reasoning already stated and will be 300,000 or 400,000 gallons per day at the respective levels.

The surface of the ground is reached at "e," and the question arises as to whether the flow can be still further increased, and if so, by what means and by how much. Pumping will be at once recognized as the means, even by laymen, but how much additional quantity may be gained, and how to determine it, and what nature of pumping is desirable, is not very well understood if inferences may be drawn from some existing water works plants.

Suppose a pit to be excavated around the well as a center to or below the level "h," 150 feet below the surface of the ground, and that the pit be kept clear of water by some means or other. If the top of the well tube remain at "e" the flow into the pit will be at the rate of 400,000 gallons per day, but if it be cut off successively at "f," "g" and "h," the flow will be respectively 500,000, 600,000 and 700,000 gallons per day, the reasoning already stated being followed. It will be seen that the ordinates "bm," etc., to the curve "a m n" represent the quantities of water that will flow with the top of the well tube at varying levels and this curve, which, within the range of observations, is closely a straight line in a number of observed cases, may be called the "discharge curve" of the well. Similarly, the ordinates "f y" and "op" to the curves "ey" and "kn" represent the increments of flow available below the surface of the ground.

Returning now to the problem of increasing the flow over and above what will take place when the well tube is cut off at the surface of the ground, the discharge curve of the well being established the nature of the pumping plant to use may be considered. It may be remarked in passing that in any practical case the engineer should, if possible, arrive at the discharge curve of a well, or battery of wells, before considering finally the pumping plant.

Note that in the cases considered in establishing the curve the

*Note: A test of a well at Savannah, Ga., by the writer, where the well tube was carried above level of flow and then shortened to secure successive lower elevations, showed the results in Fig. 105. The measurements were made by use of a rectangular weir well constructed.

pressure in the water at the top of the tube was simply the atmospheric pressure, and the pressure at any point below the top of the tube considered statically was greater than the atmospheric pressure by an amount equal to the pressure due to length of water column above that point.

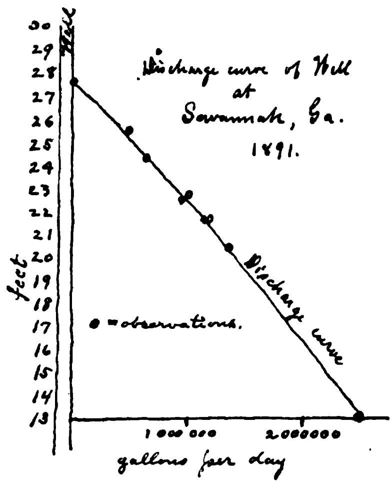


FIG. 105.

CASE I.

Let it be required to derive water from the well at the rate of 450,000 gallons per day. Set an ordinary horizontal plunger pump so that its delivery valves will be at the level of the surface of the ground, connect the well tube to suction end of pump, and speed pump to a rate of 450,000 gallons per day. A vacuum gauge tapped in the pump chamber at the level of the delivery valves will show a vacuum equivalent to a negative head of 25 feet of water. The pressure in the well tube at a point 25 feet below the surface of the ground will be equal to the atmospheric pressure. This result is necessary from the nature of the discharge curve, in establishing which it was found that, with the well tube cut off at a point 25 feet below the surface, the flow would be the rate of 450,000 gallons per day. In other words, the pressure being equal to that of the atmosphere, such would be the flow.

Other methods of pumping this volume of water are practicable. An old-fashioned deep well pump, as shown in illustrations with Mr. Johnson's paper, set anywhere in the well tube below the surface would answer if sufficiently capacious, though this volume is about the extreme limit for which such pumps have been constructed. A Pohle air lift would accomplish the same result, and with about as high efficiency as it is capable of working, Mr. Johnson's design of pumps would also answer. This case hardly

comes within the scope of deep well pumping, but leads up to a broader understanding of it. There will scarcely be any question but that the ordinary duplex plunger pump is the best suited for it, no matter how high the water is to be raised above the surface of the ground. Compared with the old-fashioned deep well pump the plant will cost little or no more, and will be far more economical. Compared with the Pohle air lift, it will cost less and be more economical, and if the water is to be raised above the surface of the ground, it will be needed anyhow. Compared with Mr. Johnson's pump it will cost less and be more economical, though the competition will be much closer than in the other two cases.

CASE II.

Suppose now it be required to derive 500,000 gallons per day from the well. The pressure in the well tube at a point 50 feet below the surface must be lowered to atmospheric pressure, and the case merges into what may be classed as deep well pumping. The old-fashioned deep well pump can no longer be considered, because it cannot be constructed to any advantage with sufficient capacity. An ordinary duplex plunger pump set at the surface of the ground cannot serve the purpose, because it cannot reduce the pressure in the well tube at anything like a distance of 50 feet below the surface. Is the field left entirely to the Pohle air lift and Johnson's pump? Here comes in the method of deep well pumping which Mr. Johnson has omitted to mention in his paper. It is possible to dig a pit around or near the well, which shall have a greater or less depth, say 30 feet in this case. The ordinary plunger pump may be set at the bottom of this pit and be connected to the well just as it was at the surface. With the delivery valves 25 feet below the surface the pressure in the well tube at a point 50 feet below the surface may be reduced to that of the atmosphere by speeding the pump to a capacity of 500,000 gallons per day.

Let it be understood here that in almost all cases the Pohle air lift is used to raise water to the surface of the ground and no higher. It might, in some cases, be used to raise water to a tower above the ground, but its efficiency falls off so rapidly as the head pumped against increases, that it is better to raise the water to the surface only and to pump the water from the surface to standpipe or into mains by use of ordinary plunger pumps at surface. It is also necessary to allow the air to free itself from the water before pumping into water mains. Now, since the practical case may be assumed to always involve lifting water to a height above the surface, a Pohle air lift plant will be considered to include not only the compressor, receiver, piping, reservoir, etc., but also the plunger pump and appurtenances: And the efficiency or economy of the plant must involve the expenses due to double pumping.

There are, then, three methods of pumping available for the case in hand, and their relative merits may be determined by summing up their several costs. The plunger pump involves the cost and maintenance of and access to the pit, but is otherwise the more economical arrangement if properly designed. The Johnson pump involves a well tube of sufficient diameter, the difficulty of overhauling the pump, the cost of the machine, etc., but may in many cases prove the better arrangement. The air lift can only come in where economy of operation is not an item to be considered, together possibly with some considerations of convenience in having all mechanism above ground.

It has been a common claim for the air lift that wherever applied it has resulted in an increased flow from the well. This has undoubtedly been the fact in a great many cases. Take the case of the well in question, for instance, and the diameter of the well tube to be anything less than 12 inches. It would not be possible to insert in the tube either an old-fashioned or Johnson deep well pump having a capacity of 500,000 gallons per day. Neither of these pumps could reduce the pressure at a point 50 feet below the surface to that of the atmosphere. The Pohle air lift could do so, however, and would thus be able to derive more water from the well than either of the other pumps. If, however, the well tube be 15 inches or more in diameter for 30 or 40 feet below the surface, then the Johnson pump would come into the field and pump the water with very much higher economy than the air lift. Or, if the conditions be favorable, plunger pumps in a pit 30 feet deep would do the same thing with more economy doubtless than either the Pohle or Johnson methods. There is nothing inherent in the air lift that causes an increased flow from a well, though under certain conditions it is capable of producing that result. The Johnson method requires only a sufficiently large well tube and the pit method requires only a sufficiently deep pit.

CASE III.

Let it now be required to derive 600,000 gallons per day from the well under consideration. The discussion will be very much the same as for the preceding case. The pressure at a point 100 feet below the surface, "g" in the Fig. 104, must be lowered to that of the atmosphere. The pit for the plunger pump method must be at least 80 feet deep which in some cases would be quite expensive, though in very many cases, especially when volume to be pumped is considerable, it would doubtless be economical. The rods of the Johnson pump would need lengthening. According to Mr. Johnson's deductions as to the economy of the air lift, it would prove a very extravagant method since the head pumped against will be 100 feet though possible where economy is not a consideration.

CASE IV.

Let it now be required to derive 700,000 gallons per day from the well. According to Mr. Johnson's curve for efficiency of the Pohle air lift, as usually installed, this method is essentially out of the field. It simply cannot lift water against a head much greater than 150 feet, at any practicable economy. The field is therefore narrowed to either the Johnson method or the pit method with ordinary plunger pump. This fact justifies a closer comparison of the merits of these two methods.

The pit method involves the expense of a pit, which, if not water tight, will have to be kept clear of surface or seepage water. Elevators may be needed for access to the pit if it is 80 feet or more deep. Pumps at the bottom of the pit will be distant from source of steam or other power, possibly requiring two men to look after the plant instead of one. On the other hand, which is desirable in water works service, two pumps may be attached to one well, one to be operated when the other is out of order, thus insuring continuous water supply if the well itself is in order. Again, if there be a battery of two or more wells, as is often necessary, tunnels from the bottom of the pit will serve as passages through which to connect all of the wells to the operating pump, thus permitting concentration of plant and increased economy. Capacity being the same, the ordinary plunger pumps can be constructed for less money and with higher economy than the Johnson pump.

While the Johnson pump avoids the necessity of a pit, unless the volume to be pumped be very large, which is not a case for which it is intended, its water end must be as far below the surface of the ground as the bottom of a pit for the other method. Like any other machine it will need periodical overhauling. In a one well plant this means that the well must be idle during overhauling or repairs, which may be a serious matter unless there be a large storage capacity available. If there be a battery of two or more wells there must be a pump in each well, which is in the undesirable direction of a scattered plant.

CASE V.

Cases which require that, at points more than 150 feet below the surface, the pressure should be reduced to that of the atmosphere, are apt to occur, and the Johnson pump and pit method will still be competitors, but their relative merits can be determined by calculations of cost and suitability in any particular case.

It must be evident that no general rule can be laid down to determine the best method of pumping to adopt for any or all wells. The conditions surrounding any particular case may vary so widely from those of another case that what may be suited to one will not be of any use for the other. It can be said in general

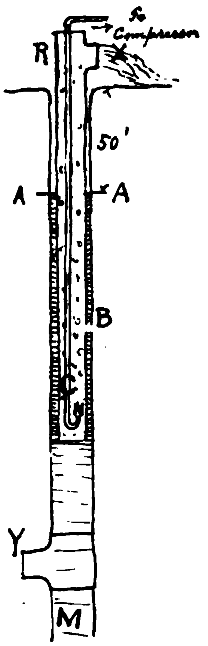


Fig. 106.

that when large water supplies are involved, say for cities of 20,000 or more inhabitants, and where atmospheric pressures in wells must be made to occur at levels below the surface of the ground, such as at Memphis, Tenn., or at Rockford, Ill., the pit method is the most advantageous. For very small supplies, where the total amount of money involved is not a momentous item in any event, and where economy in operation is not a matter of moment, the Pohle air lift and old-fashioned deep well pump may have useful application. The intermediate field affords opportunity for strife between the pit method and the Johnson pump in a degree varying with the several conditions which may environ any particular case. There may, of course, be exceptions to these general rules.

Reverting to Fig. 103 it will be readily seen that all that has been said as to Fig. 104 is equally applicable. The fact that the water does not normally rise to the surface of the ground is on indication of the hydraulic merits of the well. Comparing the discharge curve in Fig. 104 with that in Fig. 103, it will be seen that the latter is, as a matter of fact, the most capacious well because its flow will increase more rapidly as the point of atmospheric pressure is lowered below its highest level. When depressed to a level 150 feet below the surface of the ground, the flow in Fig. 104 is but 700,000 gallons per day as against 900,000 gallons for Fig. 103.

The actual condition of pressures in a well while being pumped is illustrated in Fig. 106. Let M be the well shown in Fig. 104, A being 50 feet below the surface of the ground, and 500,000 gallons per day being pumped. At the level A the pressure in the well should be that of the atmosphere.

Three cases may be cited besides the well understood case with ordinary plunger pump at the surface.

Conceive a tube R to be telescoped in the well M, an annular space being left between the two above and below A.

(1.) *Air Lift.* Let C be the pipe through which air is conducted to the well and N be its discharge nozzle. Above N, in the tube R, will be a mixture of air and water exerting a variable pressure against the sides of the tube R, and having such weight as to be balanced by the annular water column rising to the level A between R and M. With these conditions existing 500,000 gallons per day will be pumped. Should different volumes be pumped the level of the water in the annular space will be found at varying distances from the surface as indicated by the discharge curve in Fig. 104.

(2.) *Deep Well Pump.* Suppose the water end of the pump to be inserted in the tube R at the level B. Above B the pressures against the sides of R will depend upon the head being pumped against. Below B the pressures will be such, as in the case of the air lift, as to balance a water column in the annular space between the tubes the distance of the top of which below the surface of the ground will be 50 feet, if 500,000 gallons per day be pumped, 100 feet if 600,000 gallons per day be pumped, etc.

(3.) *Pit Method with Plunger Pump.* Suppose the connections to the pumps in the pit is made at Y. The tube R may be removed from the tube M for this case. The water will be found at levels in the tube M corresponding to the quantity being pumped. Fifty feet below the surface when 500,000; 100 feet below the surface when 600,000 gallons per day is being pumped, and so on, all as indicated by the discharge curve in Fig. 104.

The foregoing discussion has had reference to the case of an ideal well, the like of which has probably no exact counterpart in practice. It is to this state, however, that all deep wells approximate, and the principles involved, as set forth in the discussion, have general application. The subject is entirely too broad to be covered herein, but it may be interesting to look into it a little further.

The statements made have so far applied, in the main, to the state of affairs when but one well is involved, and, as has been seen, is sufficiently complicated. Further complications arise

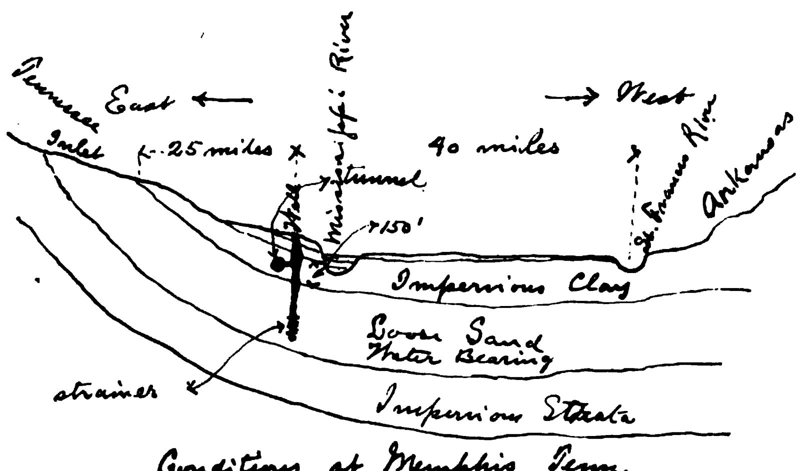


FIG. 107.

when the number of wells involved is increased. The flow or pumpage from one well will modify the results that may be obtained from a neighboring well, thus involving the level to which

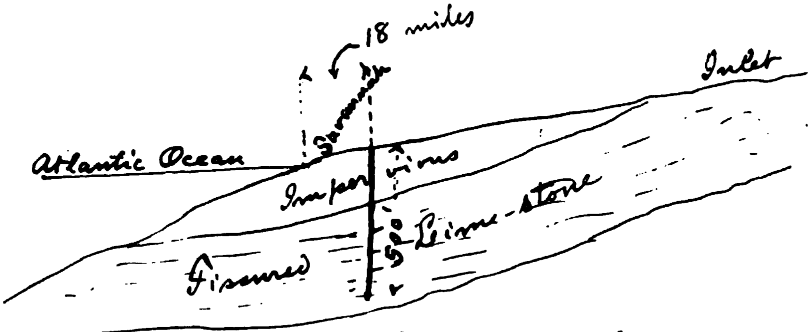
the atmospheric pressure must have existence in a well, which in turn modifies a proper determination of the nature of pumping plant. Time is too limited to go much further into this branch of the subject, but some reference will be made to it a little further on.

Brief mention of several experiences of the writer may develop some hints as to the variable nature of the problem of collecting deep underground waters in varying quantities.

MEMPHIS, TENN.

Fig. 107 illustrates generally the geological features governing the water supply at Memphis, Tenn. As indicated, the supply is derived from a stratum of clean, loose sand 800 feet thick under the city and beneath an impervious layer of clay about 150 feet thick. At the location of the plant the water rose normally to about the surface of the ground. The problem was to secure a supply of exceeding 10,000,000 gallons per day, and as a matter of fact a supply was developed ultimately which reached a maximum of 28,000,000 gallons per day on a test. A number of wells were necessary, and the officials of the water company started boring wells so that when the writer became connected with the work as Chief Engineer, the late Thos. J. Whitman being consulting engineer, he found eight wells about ready for temporary use and a number of others under way. The plan in view had been to bore as many wells as necessary, and then connect them all with a pipe line 15 feet below the surface and leading to a pump house. The pumps were to be in a pit 30 feet deep and 30 feet in diameter. The pipe line was to lead to this pit, and then bend down into the pit and act as a syphon, or else be connected direct to the suction of the large pumps. It would have been possible to have lowered the level of atmospheric pressure in the wells by this arrangement to a level of about 35 feet below the normal level in the wells. The eight wells completed were at once connected to a large pump, and numerous measurements were made to learn as nearly as possible the discharge curve of the wells individually and in battery. Without going into details as to these data it may be stated that the deduction was drawn that, counting the cost of pipe line, wells and other things involved, it was doubtful whether the supply could be secured at any reasonable cost. As a result the plans were changed. A tunnel was driven in the impervious clay indicated in Fig. 107 at a level 80 to 90 feet below the surface, to which the wells were connected through lateral tunnels as indicated. The main tunnel was made to terminate in a shaft in the center of the pump pit. The floor of the pump pit was placed at 45 feet below normal water levels in the wells. This enabled a depression of the level of atmospheric pressure in the wells to a distance of 58 feet below the normal level with no flow. This change reduced the number of wells needed, and the length of connecting channels and modified other

things in a degree that enabled an entirely successful and satisfactory installation. In fact, this change was the difference between absolute failure and radical success, and resulted simply from a study of the discharge curve of the wells and the consequent change in the plans for pumping. It is now nearly nine (9) years since that examination was made and the plant is fully demonstrated to be satisfactory.



Conditions at Savannah, Ga.

FIG. 108.

SAVANNAH, GA.

Fig. 108 is an east and west section at Savannah, Ga., where the writer developed a plant with a capacity of about 10,000,000 gallons per day. As may be seen by Fig. 105, the wells yield water very freely. This was a very fortunate fact, as will be seen. For a very considerable depth below the surface fine silts, clays and quicksands were found which would have made any plan of connecting wells to a tunnel at a low level an exceedingly difficult task. The nature of the discharge curve showed such a course unnecessary. The wells were bored 300 feet apart along a highway in which was laid a conduit 6 feet in diameter, 20 feet below the surface, through which the water flows from wells to pumps. The latter are two horizontal Gaskell pumps, each having a capacity of 10,000,000 gallons per day. Prior to constructing this plant the city was supplied with deep well water by means of 24 wells at a comparatively remote distance from the center of the city. A number of private wells were in existence besides. Inquiry developed the fact that the water in the first well bored in Savannah rose to a level of 41.00 feet above datum, as indicated in Fig. 109. At the time of the examination, the water level in wells at the waterworks was found to be 6.00 feet above datum. Going southward from the waterworks three non-flowing wells were found at distances as shown in Fig. 109, the water standing at the levels 28, 36 and 41 feet above datum. The inference was drawn that the group of wells in and about Savannah ceased to have an influence at a distance somewhat less than eight miles.

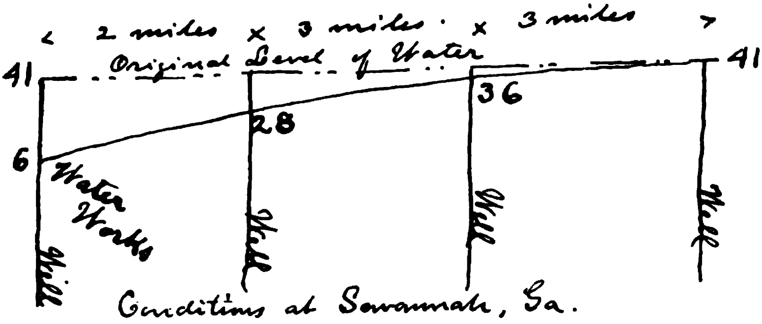


FIG. 109.

WACO, TEXAS.

Fig. 110 is a section showing in a general way the conditions at Waco, Texas, the wells being about 2,000 feet deep and the inlet about 75 miles to the northeast. It is an interesting fact that the water flows from the wells at a temperature of about 104 degrees Fahrenheit, or about as hot as one would care to have a bath.

Fig. 111 shows the conditions at the same place on a larger scale. When the water works were established a number of wells were bored, as at well A, on the hill tops and the first wells showed a pressure of about 60 lbs. or 138 feet at the surface. That is, the point of atmospheric pressure was 138 feet above the surface. The projectors of the works did not realize that the level of atmospheric pressure must be lowered as the flow increased, so

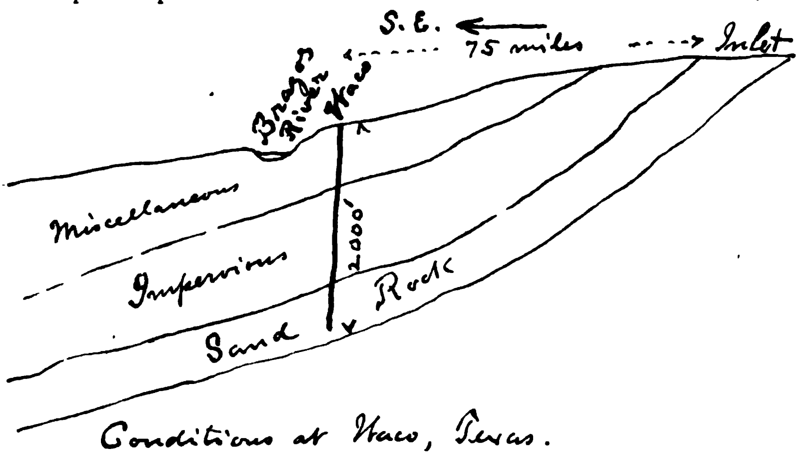
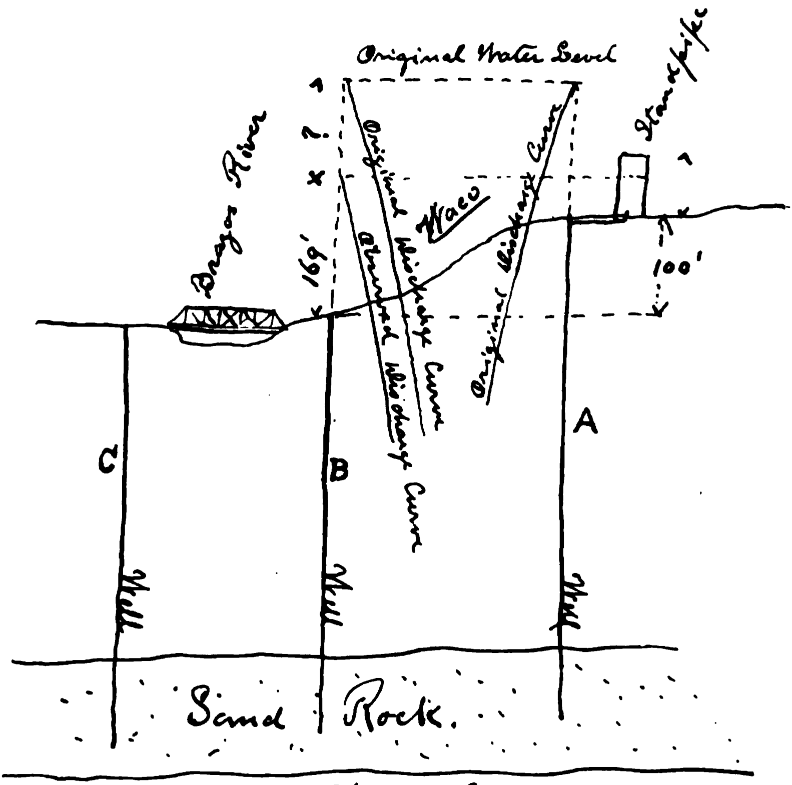


FIG. 110.

they erected standpipes on the hill tops and disposed their pipe system with the larger pipe also at hill tops. It was found that, as time went on, the height of water in the standpipes gradually became lower because the consumption of water increased, until



Conditions at Waco, Texas.

FIG. 111.

finally in 1892 when the writer examined the plant, water would scarcely rise in the standpipes during day time. In fact, during the night, when the consumption was small, the water would rise and be stored. The storage thus gained helped out during the day, though at certain times the standpipe would be nearly empty. This state of affairs showed that the time was nearly reached when the hill top wells would be useless and their cost be a dead loss, besides leaving the pipe system badly disposed. A well was bored, about this time, on the low ground at B and subsequently another at C. A close approximation was made to the discharge curve at the well B, which is interesting in reference to the question of deep well pumping. The point of atmospheric pressure with no flow was found to be 168 feet above the surface. When the level of atmospheric pressure was lowered to the surface the flow was 1,250,000 gallons per day, the intermediate curve being nearly a straight line. The point worthy of note is the very slow increase of flow as the level of atmospheric pressure is lowered.

To increase the supply to 2,500,000 gallons per day would evidently require a depression of level of atmospheric pressure to a point more than 168 feet below the surface and involve the expense of lifting all the water continuously against this head. A second well at a proper distance, as at C, would, when flowing at the surface, add a considerable volume to that flowing from B and a third well would add still more. It was a question whether it would not be wiser to bore more wells rather than undertaking deep well pumping from the one well, and it was finally so decided. If the discharge curve of the well B had shown as free a flow as in the case of the Savannah well, Fig. 105, quite the reverse would have been the case.

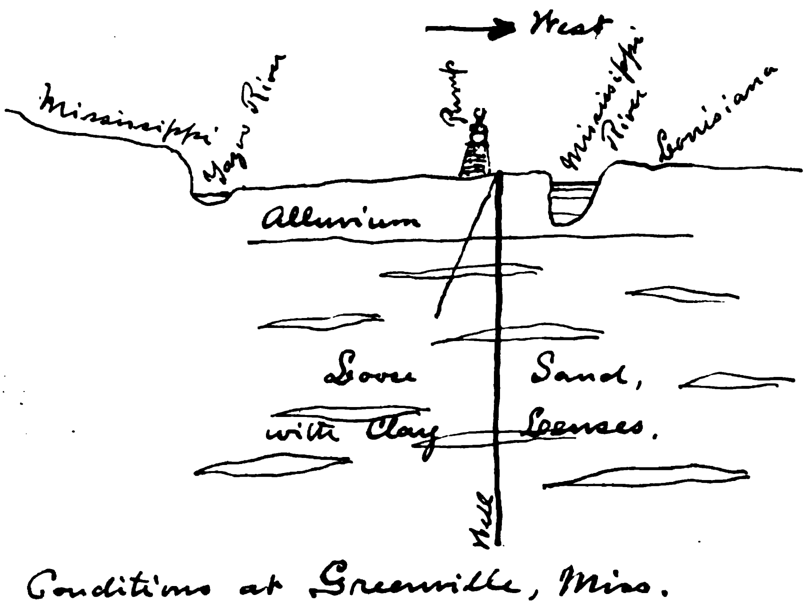


FIG. 112.

GREENVILLE, MISS.

Fig. 112 is a section showing the conditions at Greenville, Miss., just north of Vicksburg. The water rose to a little below the surface of the ground, but within reach of ordinary pumps set at surface of the ground. At the time the writer examined the situation a water company, after nearly completing works under a franchise granted by the city, failed and abandoned the work. One well had been bored, pumps erected and water pipes distributed on the streets. It is interesting to note that the pumps had been set so high as to be out of reach of the water in the well, thus indicating an entire misunderstanding as to the discharge curve of a well. This case presents an interesting study

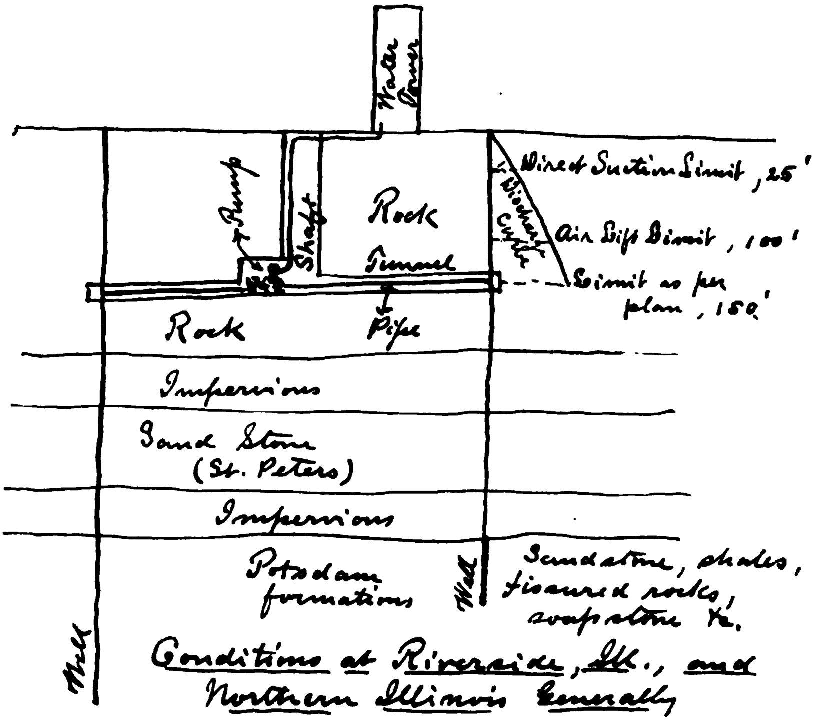


FIG. 113.

as to the best method of deep well pumping to adopt. The soil precluded anything like a deep pit on the score of expense. Ordinary pumps set at surface would require a number of wells sufficiently remote one from another. Deep well pumps or a Pohle air lift would do the work. This is evidently a case where Mr. Johnson's pump would doubtless prove the best arrangement to adopt.

NORTHERN ILLINOIS.

Fig. 113 is a section showing the conditions at Riverside, Ill., just west of Chicago, and in a general way shows the geological elements pertaining to all wells in northern Illinois. Two wells and a water tower were found to be in existence as indicated in the figure. The water rose nearly to the surface of the ground. The problem was to derive a flow of about 700,000 gallons per day and gave rise to the question of the best method of deep well pumping to adopt. Examination as to the discharge curve of the wells showed that, if the level of atmospheric pressure be lowered to a point 150 feet below the surface, the desired volume of water would probably be secured. The wells are of small diameter and the frictional resistance in them may prove an item that will de-

feat securing so much water, in which event a new well of larger diameter will be needed which will doubtless yield 1,000,000 gallons per day with atmospheric pressure 150 feet below the surface. Surface pumps and the Pohle air lift were discarded at once, as was also the old-fashioned deep well pump. Figuring up the cost of the several items showed that the pit method was the most economical. Consequently the plans were drawn for a shaft as shown in the figure, with a pump room at its bottom; also providing for tunnels, piping, etc., as shown. The work is now under construction, though progressing slowly, for reasons, however, which have no relation to the merit of the plan.

It may be said, in conclusion, that at Rockford, Ill., a plan very similar to that for Riverside has been recently adopted, the shaft being not quite so deep and the quantity of water sought being 6,000,000 gallons per day. Our fellow members, Mr. D. W. Mead and Mr. Chas. C. Stowell, are the engineers of the proposed arrangement there.

Discussion by A. F. Nagle, M. E.

Mr. President—Although not a member of your society, I am requested to discuss this paper and hence present the following: Any data pertaining to the subject of deep well pumping is of interest and instruction to the engineer, and it is therefore with gratitude toward the author that I read his paper.

The paper divides the subject into two broad types; first, what may be called the pneumatic or air lift type, and second, the mechanical or pumping type. Each type must be again subdivided into the pump or lifting apparatus proper and the power generating apparatus provided for operating the pump. I shall confine my marks principally to the former division of the subject—the pump proper.

Let us look at the air lift for a moment. What is its efficiency? The author (page 175) quotes Browne and Behr as finding it rarely as high as 50 per cent. At Rockford, Ill., tests showed 38 per cent under a lift of 85 feet. I believe this to be quite correct. I regret to say that I have not made, or seen made, an analysis of the action of the air lift pump and hence I am not able to say what may be expected of it, but actual experience seems to point to an efficiency of about 38 per cent or 40 per cent. This is, of course, exclusive of the air generating plant. I have some data pertaining to the artesian wells at Oak Park, Ill., which gives almost identically the same efficiency as that quoted by Mr. Johnson; namely 37 per cent. The author finds the combined efficiency of the air lift and compressing machinery to be 24 per cent. At Oak Park, I find only 18½ per cent, but, as the data was given me by the superintendent from memory only, it being the general daily performance, I am inclined to accept Mr. Johnson's result as the more reliable of the two. It should be noted,

however, that this is only the mechanical efficiency of the plant and does not take any account of fuel economy.

Let us now pass on to the mechanical pumping process. What does the author find to be the efficiency of the apparatus described?

The first pump mentioned by Mr. Johnson I understand to be of the ordinary type. It was tested under two different speeds. This is a good experiment to make but, unfortunately, there are discrepancies in the data and conclusions given, which need explanation to make them acceptable. I believe the only difference in the two tests made on the De Kalb pumps was one of speed. On pages 181 and 182 we have the data. Please refer to these pages. I wish to call your attention to what is termed "slip of valves," (it may be slip of plunger,) but you will observe that it is given as 20.2 per cent at the lower speed, and 9.2 per cent at the higher. The valves used in this pump are ball valves, and the author gives no data on the size and weight of these ball valves. I cannot imagine such a slip of water through a ball valve as 20 per cent, or even 9 per cent. If it should really be as much as 9 per cent the valve must be exceedingly light, and have a high lift, thus permitting it to close very late. Is not such late closing conducive to shocks and noises at each reversal of the plunger? If the valve closes late, the loss of water through it would be greater as the speed increased, instead of less as given in this paper. If the slip should be past the plunger instead of through the valve, then the percentage of slip should be inversely proportional to the speed of the plunger. That is, if 9 per cent be the slip at 33 revolutions per minute, it should be 13 per cent at 22.75 revolutions, instead of 20.2 per cent as given.

A properly designed pump valve in all standard city pumping engines, either of the plain rubber type or of the double beat type, does not have more than 1 per cent to 1½ per cent slip (so called) and, as our formulas for weir measurements are not accurate beyond that degree, I am of the opinion that a good pump valve has no slip at all, or practically none, and what is attributed to valve slip is either slip of the plunger or errors of observation by the experimenter.

Let us, for a moment, turn to the test of Mr. Johnson's improved pump recorded on page 187. You will there notice that the slip of valve is given at only 3.3 per cent. Why should this pump have so much less slip? The author has not explained the difference in the construction of the valves used in the two cases. Mr. Johnson used a double beat Cornish valve, I believe. Even the 3.3 per cent recorded I believe to be excessive, but if we accept it, the efficiencies of the two pumps—the Johnson and the ordinary—are as 67 to 62.3 and this difference is really a difference in valves, and not in types of driving mechanism. If we credited the ordinary pump with a slip of only 3.3 per cent its efficiency would be increased to 66 per cent, or about the same as

the Johnson pump. I am perfectly willing to accept Mr. Johnson's statement that the improved (though undescribed) mechanism is conducive to smoother working than has heretofore been obtained, but I cannot discover from the data given that it has resulted in any higher efficiency of pump, nor are we absolutely certain that the better working of the Johnson pump is entirely due to its peculiar driving mechanism. We have already observed that the different valve constructions are important factors in the smooth working of pumps.

If any direct comparison of efficiencies can be made at all, it seems to point rather the other way and show a better efficiency for the ordinary pump. Mr. Johnson's pump had an efficiency of 67 per cent when working at a piston speed of only 40 feet per minute, whereas the ordinary pump, corrected for valve action, had 66 per cent efficiency when working at a speed of 99 feet per minute. I confess I cannot tell just what the decrease of efficiency would be for an increase of speed, but that it would be less under normal conditions of pump action is certain.

Mr. Johnson's pump mechanism has a travel of four feet per revolution while the effective displacement of the plunger is only 41.25 inches, a loss of 14 per cent in the frictional work of the plunger. Just what the frictional work is I cannot tell.

The Johnson pump also had an advantage in obtaining a higher efficiency over its rival, in having nearly double the head, efficiency always being increased by increase of load.

First-class modern pumping engines obtain efficiencies of fully 90 per cent which includes the friction of the engine that drives the pump. Probably the pump alone has an efficiency of 97 or 98 per cent. If the mechanically driven deep well pump obtains an efficiency of only 67 per cent, cannot this be increased so as to approach to that of our best type of pumping engine? I am sure that this difference is not to be accounted for or dismissed by saying that the valve area is necessarily contracted much below the area of the plunger. The Johnson pump, 6¾-in. in diameter, when discharging three times the quantity given in this test, or 225 gallons per minute, would give a mean velocity of flow of only 2 feet per second. If the valve area was reduced to one-fourth the area of the cylinder, the mean velocity of flow through the valve would then be only 8 feet per second, by no means an objectionable velocity for high lift.

Where, then, is the great loss of efficiency? We must look for it in the driving mechanism itself and in the piston packing. The small cylinder with three or more cupped leather or hydraulic packing rings no doubt is conducive to a disproportionately large percentage of friction over the ordinary pumping engine packing in large cylinders. This friction can probably not be reduced. It would not do to dispense with packing rings altogether and trust to grooves in the plunger.

The sand usually found in these wells would wear the plunger

so much that this, together with the slow speed, would make the leakage exceed the present loss in friction of packing. It is therefore not likely that we can look for any improvement in efficiencies of these pumps, viz.: 67 per cent.

But if, with the air lift, we can obtain only 38 per cent, why does this find a market at all? Is it not largely due to the fact that, aside from the question of simplicity and durability of mechanism, the capacity of the air lift exceeds that of the mechanically driven pump? Mr. Johnson's pump made 11 revolutions per minute. He gives 25 as the maximum practicable speed for any deep well pump. This would increase the delivery of his pump to about 160 gallons per minute. The air lift would probably deliver 450 gallons through the same sized well, which is about three times the capacity. In other words, three wells and three plants for mechanically driven pumps would be required to do the work of one air lift pump.

With these facts before us we can easily compute, from known conditions, whether the saving effected in fuel would pay for the additional investment required.

A word as to the generating plant. Mr. Johnson gives the combined efficiency of the entire air lift plant at 24 per cent, which I am inclined to accept as nearly correct. Still, as my data relating to the Oak Park plant gives only 18½ per cent, as Mr. Johnson's own table IV, page 174, gives the machine efficiency of an air compressing plant, working under conditions like those under discussion, at about 50 per cent, and as our air lift pump efficiencies agree at 38 per cent, the combined efficiency would be reduced to 19 per cent. For practical guidance, therefore, I would be inclined to place the efficiency of a complete air lift plant at about 20 per cent.

Mr. Johnson finds the efficiency of the electric motor used 81 per cent and of the gas engine employed 53 per cent. If we use a steam engine having a mechanical efficiency of 75 per cent (a small engine), we would have a combined efficiency of an entire mechanically driven deep well pumping plant of just about 50 per cent as compared with 20 per cent efficiency of an air lift plant of three times the capacity from the same well.

To sum up, I think Mr. Johnson should have submitted drawings of the two forms of pump valves used in the two cases under discussion. A drawing of his improved driving mechanism would have also been a help to us. While I have no disposition to underestimate the importance of his new mechanism in the case reported here, I cannot learn that it has resulted in any economy, nor can I avoid the conclusion that the facts submitted prove the superiority of double beat Cornish pump valves over ball valves in the reduction of slip, rather than the superiority of Mr. Johnson's improved driving mechanism over the ordinary one. And even the improved mechanical action of the Johnson mechanism might be attributed to the better action of the quick closing

double-beat Cornish pump valve rather than to the peculiar driving mechanism.

Discussion by CHAS. L. HARRISON, Mem. W. S. E.

In the discussion by Mr. E. E. Johnson of Deep Well Pumping, it appears that the old type of pump is limited in capacity on account of the limit of the speed at which it may be operated. It is also objectionable for pumping from great depths on account of the long connecting rods and the heavy service demanded of them.

The efficiency of the Pohle Air Lift is discussed from tests made when in actual operation. It appears, Fig. 91, that it cannot be useful in lifting water more than 150 feet, and is not an economical pump for much lower lifts. There are some points affecting the economy of this pump that are not brought out by this paper nor by the discussion of it by the President, Mr. Thos. T. Johnston.

The results of tests made by Messrs. Ross E. Browne and H. C. Behr, at San Francisco, were published in the Engineering News, June 8, 1893. The pump used by them and the tabulated results are reproduced here:

RESULTS OF TESTS OF AN AIR LIFT PUMP BY MESSRS. ROSS E. BROWNE AND H. C BEHR.

Water lift (H), ft.	Submersion (h), ft.	Pressure corresponding to (h), lbs. per sq. in.	Pressure in receiver above atmospheric, lbs. per sq. in.	Weight of air supplied, lbs. per sec.	Water pumped, cu. ft. per sec.	Work of isotherm compression (L), ft. lbs. per sec.	Work of water lift (W), ft. lbs. per sec.	Ratio $\frac{H}{h}$	Per cent. efficiency $\frac{W}{L}$ of pump
15.3	36.3	15.7	23.1	.082	.3540	2,105	338	0.4	16
15.3	36.3	15.7	17.4	.043	.3182	918	304	"	33
15.3	36.3	15.7	16.2	.028	.2558	572	244	"	43
35.1	53.2	23.1	30.6	.078	.3136	2,459	687	0.6	28
35.2	53.1	23.0	26.8	.061	.3014	1,770	662	"	37
35.0	53.3	23.1	24.9	.041	.2425	1,150	530	"	46
35.0	53.3	23.1	24.0	.030	.1941	802	424	"	53
20.3	31.3	13.6	21.9	.082	.2954	2,050	374	0.7	18
20.3	31.3	13.6	15.1	.040	.2398	769	304	"	39
20.3	31.3	13.6	14.4	.032	.2086	594	264	"	44
26.3	25.3	11.0	20.3	.083	.2296	2,013	377	1.0	19
26.3	25.3	11.0	15.8	.059	.2050	1,178	336	"	29
26.3	25.3	11.0	12.5	.033	.1420	558	233	"	42
75.2	53.0	23.0	31.1	.078	.1755	2,408	824	1.4	34
75.4	52.8	22.9	30.8	.078	.1799	2,454	846	"	34
75.3	52.9	22.9	27.6	.059	.1488	1,716	700	"	41
75.3	52.9	22.9	25.4	.041	.0757	1,156	356	"	31

Water lift (H), ft.	Submersion (h), ft.	Pressure corresponding to (h), lbs. per sq. in.	Pressure in receiver above atmospheric, lbs. per sq. in.	Weight of air supplied, lbs. per sec.	Water pumped, cu. ft. per sec.	Work of isotherm compression (L), ft. lbs. per sec.	Work of water lift (W), ft. lbs. per sec.	Ratio—$\frac{H}{h}$	Per cent. efficiency $\frac{W}{L}$ of pump.
54.7	33.6	14.6	23.8	.081	.1538	2,151	5 5	1.6	24
54.7	33.6	14.6	17.4	.049	.0824	1,056	281	"	27
54.5	33.8	14.6	16.1	.033	.0576	681	196	"	29
31.5	20.1	8.7	18.9	.084	.1488	1,922	292	1.6	15
31.5	20.1	8.7	12.3	.052	.1126	860	221	"	26
31.3	20.3	8.8	10.0	.031	.0633	432	124	"	29
36.0	15.6	6.8	17.1	.086	.0693	1,818	156	2.3	9
36.0	15.6	6.8	10.1	.052	.0424	749	95	"	13
36.0	15.6	6.8	7.4	.029	.0093	323	21	"	7
62.1	26.2	11.4	20.6	.083	.0931	2,041	361	2.4	18
62.4	25.9	11.2	15.2	.056	.0663	1,090	258	"	24
62.4	25.9	11.2	12.3	.029	.0185	489	72	"	15
69.9	18.4	10.0	18.8	.084	.0338	1,904	1 7	3.8	3
69.6	18.7	10.0	11.9	.050	.0067	837	29	"	3
41.0	10.6	4.6	15.8	.087	.0146	1,757	37	3.9	2
41.0	10.6	4.6	7.1	.035	.....	382	...	"	..

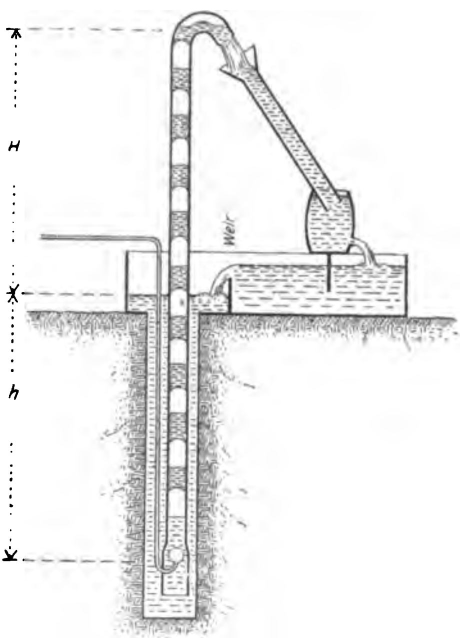


FIG. 114. Pohle's Air Lift Pump, tested by Messrs. Browne and Behr.

Referring to the table, it will be seen that when the pressure of the water (h) Fig. 114, was 15.7 lbs. per sq. in. and the air introduced into the bottom of the discharge pipe at a pressure of 16.2, 17.4 and 23.1 lbs. per sq. in., the corresponding efficiencies of the pump were 43 per cent, 33 per cent and 16 per cent, and the quantities of water pumped in cu. ft. per sec. for these pressures were 0.2558, 0.3182 and 0.3540. Other figures in the table show similar results. These experiments show the greatest efficiency of the Air Lift Pump is obtained when the pressure of the air introduced into the well is just enough to overcome the pressure of

the water column (h) Fig. 114. A greater air pressure will pump more water, but will very materially reduce the efficiency of the pump. It will be seen, therefore, contrary to the popular notion, that the economical operation of the Air Lift Pump requires the most careful and intelligent management. It is doubtful if the efficiency of any other form of deep well pump could be so easily affected. The pump used by Browne and Behr was such that a uniform water pressure (h) could be maintained, but in deep well pumping we do not meet with such conditions. When no water is being pumped from the well the water will stand at a given point, as at "A" in Fig. 103 of Mr. Johnston's discussion. Suppose the air to be introduced into the well at a point 231 ft.* below A, the water pressure at this point will be 100 lbs. per sq. in. To overcome this and start the water flowing in the well would require an air pressure somewhat in excess of 100 lbs. per sq. in. If 450,000 gals. per day is being pumped from the well the water level will be reduced to (b), and the water pressure at the nozzle of the air pipe will be 78.3 lbs. per sq. in.—if 900,000 gals. per day is being pumped the water level will be at (c), and the pressure at the nozzle of the air pipe will be 56.6 lbs. per sq. in. In actual practice the water level in the well, and therefore the water pressure at the nozzle of the air pipe, varies accordingly as more or less water is being taken from the well. To obtain the best results, the air pressure should be made to vary in the same ratio. Assuming that it be required to obtain 900,000 gals. per day from this well, and the air to be introduced into the well at a point 231 ft. below (A), the compressor must be so constructed as to develop an air pressure greater than 100 lbs. per sq. in. to start the water column. When 900,000 gals. is being taken from the well the water level will be reduced to the point (c), giving a water column of 131 ft., or a pressure at the nozzle of the air pipe of 56.6 lbs. per sq. in. The most efficient working air pressure to overcome this would be, say, 58 lbs. per sq. in. We have then a machine working at a pressure of 58 lbs. when it is designed to develop a pressure of 100 lbs. It is doubtful if the best results can be obtained under these conditions.

It is to be regretted that Mr. Johnson has not given us a full description of the construction of his new type of pump, but the diagram of its motions given in Fig. 97 would indicate that he has made a great improvement over the old type of pump. The results given in table IX show an efficiency that should warrant its adoption for deep well pumping in many cases.

Discussion by J. F. Lewis, Mem. W. S. E.

Mr. Chairman—This is a very interesting paper, and Mr. E. E. Johnson is to be congratulated upon his improvement in deep well pumps, which, without question, is much needed.

*Note.—The experiments of Browne and Behr show the best results are obtained when the submersion (h) is greater than the lift (H).

It has been so fairly and ably discussed by our president, Mr. T. T. Johnston, Mr. Nagle and Mr. Harrison, that there remains but little to be said. I wish, however, to second most heartily what Mr. Harrison says in regard to pressures and volumes, for it seems to me that the success or failure of air lift pumping depends very largely on the proper volume and pressure of the air to the amount of water to be raised.

I am free to acknowledge that I know very little of deep well pumping and what I have gathered from experience has been in the past year or two, therefore I do not feel competent to add much to what has already been said, only perhaps to correct, as far as possible, whatever false impressions may be gathered from the test in Rockford, as stated in Mr. Johnson's paper.

When this plant was installed, the question of economy did not enter into its operations in the least; it was simply to give the city a certain quantity of water from the four St. Peter wells in a given time, viz., 2,000,000 gallons in 24 hours. This was the only question that entered into the transaction. The city was told that a much more economical plant could be put in, which is true, but what they wanted was water with as little expense as possible for plant. This was given to them, and I am free to say that I do not believe that under the same conditions, there is a deep well pump made—old or new style—that would have furnished the same amount of water. I believe that an air lift plant can be installed that will at least reduce the present cost one-half to two-thirds. There is also much to be said in the saving of repairs and labor over the old style of deep well pump. I remember at one place where we installed an air lift pump, after using some months, the superintendent said if he ever had anything to be thankful for, it was the air lift pump, as he had been able to sleep every night and go to church Sundays--a thing he had not been able to do before since he took charge of the water-works, as Sundays and nights he had to repair the deep well pumps; but, since starting the air lift, besides getting 200 gallons per minute more water, they had not stopped once for repairs. The same can be said of each and every plant, and there are hundreds of air lift plants running today; they are being installed faster than any other style of pump.

I also wish to correct Mr. Johnson in his "assuming" a consumption of steam of 50 lbs. per H. P. hour, as I think it much too large. There was no test of this made, for, as I said before, economy did not enter the question—it was simply quantity of water lifted, but I quote from a very careful and exhaustive test made by Prof. J. E. Denton and D. S. Jacobus, Vol. X, Tansactions American Society of Mechanical Engineers, with a 17×30 Duplex Steam Air Compressor, same style as the Rockford machine, having Meyer adjustable cut-off valves on steam cylinders, poppet valves on air cylinders. Duration of test, seven days. Tests were made on this engine with cut-off ranging from 7/8 to 1-25

stroke, with boiler pressure from 90 to 30 lbs. per sq. in. Boiler pressure at 90 lbs. revolutions 60, steam consumption was 27.5 lbs. per hour per H. P. With the boiler pressure 90 lbs. throttled to 56 lbs., revolutions 62.57, cut-off ⅞, water consumption was 39.9 lbs. per hour per H. P., the loss in economy for ¼ cut-off at different speeds is at a rate of 1-12 of a pound of water per H. P. for each decrease of revolutions per minute from 86 to 26 revolutions, and at the rate of ⅝ lbs. of water per H. P. below 26 revolutions per minute. Test also showed that ¼ cut-off was more economical than ½ or ⅛ for all speeds. He also states the steam per hour per H. P. may be regarded as about 25.5 at ¼ cut-off, 90 revolutions per minute, 90 lbs. steam. The water consumption was measured by condensing the exhaust steam through surface condenser from one of the steam cylinders, (the other exhausting in atmosphere), water being weighed.

The reason for having late admission in the steam cylinder is that the air left in the clearance space is sufficient to cushion piston at end of stroke. Therefore, there is no cushion needed in the steam end, as the air cushion is sufficient to carry engine over centers. The amount of air left in the clearance of the air cylinders does not represent the loss in power but a slight loss in volume.

The compressor at Rockford cut-off from ¼ to 2-5 and should not consume more than 28 lbs. to 30 lbs. of water per hour per H. P.

Also from a test made by G. D. Brooke, M. M. of the St. P. & D. Ry., with a 10×16 duplex Air Compressor with Meyer valves. Steam pressure 70 lbs. Air 110. Revolutions 35. Steam per I. H. P. per hour 29.33. This machine has compound air cylinders and intercooler. Cubic feet of free air compressed to 110 lbs. pressure, per pound of steam, at 54 lbs. initial pressure—10.6.

Advantages of the air lift are, machinery is all above ground and concentrated, requiring less attendance than any other system; great increase of water; no repairs whatever. If water falls you can follow it down, and by installing an economical air compressor with Corliss compound condensing engine and compound air cylinders with the new system of piping the wells which we have recently adopted, there is no question but what the cost per million gallons will compare favorably with any system that is in vogue.

We will soon have data from what we consider a fairly economical plant, as to the cost of pumping water by this system, as we have recently installed a plant pumping several wells.

Regarding the cost at Rockford we have data for two months —October and November, 1896—water pumped, 153,023,000 gallons. The conditions were: steam pressure, 80 lbs.; air pressure for 12 hours during the day, 66 lbs.; 12 hours night time, 70 lbs; revolution of compressor during the day, 48; during the night, 42. The lift of water about 25 ft.; coal burned, 215 tons, costing $337.08, or $2.16 per million gallons. This lifted the water to

the top of the ground; then it is pumped from the reservoir by low-service pump. Total cost of fuel during the two months for putting the water into the mains, $3.85. Assuming that this Compressor had been an economical one, with compound condensing Corliss engine, no doubt but what the fuel could be at least divided by 2. This would lessen the cost of delivering this amount of water into the mains $1.08, or total cost of $2.77.

Discussion by D. W. MEAD, Mem. W. S. E.

Mr. Chairman: There is no question but that every system of pumping has both its advantages and its disadvantages. The Pohle air-lift plant installed at Rockford has undoubtedly served its purpose. The question at Rockford for the last few years has been a question of securing sufficient water, and the question of the expense of obtaining the water was secondary to the question of securing pure water for the public supply.

About 1891 the demand for water at Rockford began to exceed the supply furnished by the flow of the five artesian wells which had been drilled at that place. The St. Peter sandstone was being investigated as a source of supply, and a number of eight-inch wells had been drilled into that deposit. Three wells were fitted with direct acting steam deep well pumps of the same general type shown by Mr. Johnson in his second illustration. These pumps are a type that must use a large amount of steam. The stroke is usually from two to three feet in length and steam is admitted for the full stroke. The action of the engine is slow and the cylinder condensation unquestionably large.

In 1893 I had occasion to observe the duty of one of this type of pumps at De Kalb, Illinois, where the observations were made on the regular running efficiency of the pump, but including as well the boiler plant. In this case the coal consumed amounted to about fifty-eight pounds of coal per horse-power hour. But a large part of this was doubtlessly due to a poor boiler plant, which may also explain in part of the high coal consumption at the places which Mr. Johnson notes. As previously stated, this type of pump was first placed on the wells at Rockford, and the amount of water obtained was, of course, increased, but while sufficient for the first twelve or eighteen months, it was not a sufficient quantity to keep pace with the increasing demand for water for any great length of time, and some other method of increase was found necessary. The question of greater economy was also considered, but was largely lost sight of as "more water" was the great necessity, and this necessity finally led to the purchase of a Pohle air-lift plant. The air-lift plant has, I think, satisfactorily supplied the quantity of water used during the last two years, although great care and economy of water has been necessary in dry seasons. Little if any water has, I believe, been pumped into the system at Rockford since it was installed, while

before that, even while the deep-well pumps were running, it was quite a frequent occurrence to open the river gate and let the river water, a water but little better than Chicago river water, into our mains, in case of fire or other emergency.

The practical results of any system of pumping are shown in the actual cost of the resulting work. The result of the use of the steam deep well pumps and the Pohle air lift system is shown very markedly in the following table which gives the cost of pumping per million gallons at Rockford, Ill., based on the pumping station expenses. In this table, which shows the cost of pumping based on pumping station expenses from 1878 to the present year, it will be seen that the cost of pumping per million gallons has gradually decreased as the amount of water pumped for the year increased, until in 1890 and 1891, it reached a minimum of about $8.37. In 1892 and 1893, the deep well pumps were operating In 1892 they were used only a portion of the time; in 1893 they were in operation during the entire year. In 1894 the Pohle air lift system was installed and in 1894, 1895 and 1896 is seen the result of its operation. It should be noted in considering these figures since 1892 that the water has been raised a greater distance than was formerly done when the water was pumped once, and for this reason, we should expect an increase in cost in proportion at least to the head pumped against. The actual resulting costs, however, are not commensurate with the extra height which the water was lifted, but are very much greater,

The column showing the cost of fuel used does not in all cases give the actual amount of fuel used in the entire plant, but a portion is also included in the figures placed below the table in 1892, 1893 and 1894. These amounts are the estimates of the cost of deep well pumping and pumping by the air lift made by the stationary engineer of the plant. All steam however, was taken from the same boilers so that the estimate is not exact and it is an open question whether the amounts stated are approximately correct or not. The totals, however, for the year are correct and the resulting cost per million gallons is also correct. Sufficient data is not, however, available to give all of the information which would be desirable.

The Pohle air lift system has its chief use where quantity of water is the chief concern and where this is to be taken from single wells and where cost of operation is not a large consideration. It is the best combination pumping appliance which has been placed on the market for obtaining a large quantity of water from a small hole. For instance, some preliminary experiments were made with the Pohle air lift on Well No. 4, at Rockford. This is an eight-inch well, drilled into the Potsdam sandstone and flows at the surface. This well flowed at the outlet of the discharge pipe about 150 gallons of water per minute. When the air lift was started with a six-inch pipe inside the eight-inch casing, the

amount of water was increased to about 650 gallons per minute, and when the six-inch pipe was taken out and the eight-inch casing used for the discharge outlet, the discharge was increased to over 900 gallons a minute. It is probably impossible, with an ordinary power pump, to obtain such a large discharge from a small hole as this experiment shows, and in places where it is a question of volume and not economy, the Pohle air lift, I believe, has this advantage over anything else that has been offered.

When the matter, however, is considered on the basis of economy the air lift loses its advantage and this we should expect from the nature of the case. In the first place, it is a principle that is well understood by all engineers that you cannot transform energy without some loss. When, therefore, you transform coal into heat and heat into steam and steam into compressing air, and expanding air into raising water, you are transforming energy a great many times, and must meet with a great many losses. The most simple way in which you can apply the coal, leaving other things out of consideration, the more economically you can expect to do the work. I believe, therefore, that economy in deep well pumping must necessarily come through simplifying the mechanical details of the plant and applying power as directly as possible.

FIG. 115. Direct Acting Steam Deep Well-head with Fly-wheel.

The direct acting steam deep well pumps are so expensive in operation that it is a wonder that they have staid on the market as long as they have. In some cases an improvement has been attempted by using a fly-wheel in connection with the ordinary long steam cylinder. (See Fig. 115.) This seems to be a move in the right direction to use steam expansively. Another design is shown in Fig. 116 with the steam cylinder horizontal. In this case the steam cylinder need not be of the same length as the pump cylinder and there is no necessity for moving the steam end when the water end has to be examined or repaired. The use of a fly wheel with this last design would seem to be an additional improvement. Fig. 117 shows another attempt to improve the direct acting steam deep well pump, especially in the line of securing more water. This pump is

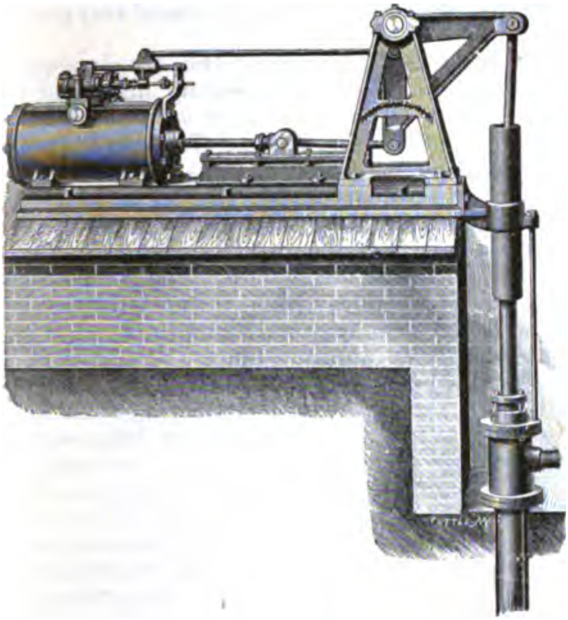


FIG. 116. Horizontal Artesian Well Engine.

FIG. 117. Direct Acting Deep Well Pump Head.

double acting, and the amount of water obtained by it from the same sized well is almost double the amount possible with the single acting head.

I have never had experience with these types of deep well pumps and cannot give actual results obtained by their use. They seem, however, to contain improvement on the ordinary type of direct acting deep well pump and to this extent merit attention.

In deep well pumping I think that maximum economy will be secured by combining economical motors with a pumping head of the general type of either the double acting head as used at De Kalb, or the very interesting pump head designed by Mr. Johnson. In these cases, if high efficiency of the machinery can be obtained by careful design and careful mechanical construction and a high grade of intelligence used in operating them, first class results can be obtained. In such cases, almost any steam consumption desired in the motor used to operate the pump can be obtained. By using compound condensing Corliss engines, a steam consumption of about 16 pounds of steam per horse-power hour can be secured, and by triple expansion somewhat lower steam consumption can be secured (say 13 or 14 pounds). Such results are difficult to obtain where small amounts of power are used, although I understand that with the William's engine an actual test of a twenty horse-power engine was made, where only about 13 pounds of steam per horse-power per hour was used. If

such motors can be used in connection with power heads, very good results are possible.

I have watched with a great deal of interest the development of Mr. Johnson's idea in this new power pumping head and I believe he has designed something that will be of very great importance among deep well pumping appliances. The use of deep wells is very rapidly increasing, especially in smaller cities and towns around about Chicago. Most of the smaller towns, are looking for deep supplies, because they can obtain good water from such sources and they also obtain an unfailing supply in most instances where they go to the large underlying sandstone beds which have large outcrops and which are not affected to any great extent at least by local or seasonal changes.

I discussed at some length at another place (See "Hydro-Geology of the Upper Mississippi Valley and some of the Adjoining Territory," Journal of the Association of Engineering Societies, Vol. XIII, No. 7, July '94) the geology of the upper Mississippi region and I will not enter into that at this time, but I will say, in connection with Mr. T. T. Johnston's discussion, that in some experiments made by Mr. Fanning and myself in Rockford in 1891 and in experiments made since by Mr. C. C. Stowell, we find that the curve of the discharge of the artesian wells at Rockford is practically a straight line, and that the amount of water increases almost directly with the distance at which you take the water below the point at which the water will stand in an open pipe. Thus, if the water will rise and stand ten feet above the surface and will flow 100 gallons at the surface, you can count on getting 200 gallons at a point ten feet below the surface, and so on.

The value of these artesian waters I think should be fully appreciated in searching for water supplies for the smaller cities. We have a great many modern filters which are undoubtedly very efficient in purifying water for use, but in such cases careful supervision and careful work is the price of immunity from poor water and consequent decrease. Matters which depend upon the careful supervision by men are subject to the neglect of men and impure water, if filtered, is very likely to get into the mains at times. For this reason, it is advisable wherever possible at reasonable cost to use the deep waters which are so deep that they are not and cannot well be contaminated from the surface if they are properly taken care of by the right construction of deep wells. Certainly our smaller towns are recognizing this and the larger towns are also beginning to recognize the great value of such sources of supply.

Rockford is depending entirely on deep waters for its supply. Ottawa, Aurora, Joliet and quite a number of other cities are looking toward such sources and a very large number of smaller ones in our immediate vicinity are depending upon artesian water. These extended and extending uses makes the question of deep well machinery a very important one.

COST OF PUMPING PER MILLION GALLONS AT ROCKFORD, ILL., BASED ON PUMPING STATION EXPENSES.

Year.	Fuel.	Salaries.	Expenses.	Total Cost.	Million Gallons pumped for year.	Cost per Million Gallons.
1878	$ 974 20	$ 2,980 99	$ 925 25	$ 5,285 95	183.0	$ 28 35
1879						
1880	1,549 12	2,831 20	585 16	4,965 48	288.0	17 20
1881	2,181 56	2,893 50	958 31	6,033 37	342.2	17 65
1882	2,200 87	3,050 00	946 12	6,196 99	366.7	16 80
1883	1,951 29	3,050 00	764 36	5,765 65		
1884	2,785 30	2,900 00	904 02	6 589 32	460.2	14 30
1885	1,457 58	3,050 00	573 49	5,081 07	469.9	10 80
1886	1,653 76	3,206 07	666 15	5,525 98	530.0	10 43
1887	1,344 64	2,430 59	412 61	(a) 4,187 84	433.6	9 66
1888	1,855 13	4,043 86	719 47	6,618 46	716.7	9 23
1889	1,788 91	4,123 34	764 74	6,676 99	728.2	9 17
1890	2,375 33	4,236 12	646 05	7,257 50	866.2	8 37
1891	2,104 60	3,863 16	751 75	6,719 59	801.2	8 38
1892	1,893 06	3,881 50	864 37	(b) 7,748 07	797.6	9 72
1893	2,124 18	4,051 26	914 40	(c) 9,409 73	859.4	10 95
1894	2,208 08	4,049 20	841 20	(d) 11,608 33	926.0	12 53
1895	5,163 56	6,178 60	1,095 51	12,437 67	1,079.9	11 52
1896	4,877 71	5,539 98	1,220 50	11,638 19	1,031.7	11 28

(a) for eight months only.
(b) Total includes $1,109.14 cost of deep well pumping.
(c) Total includes $2,319.89 cost of deep well pumping.
(d) Total includes $4,509.85 cost of air lift pumping.

Discussion by VICTOR WINDETT, Mem. W. S. E.

Mr. Chairman: The matter of efficiency of pumps has been spoken of, starting from the coal, and Mr. E. E. Johnson in the course of his paper spoke of the efficiency of the plant starting from say 1,000 pounds of steam.

It would seem where we are talking about the efficiency of pumps, we would better take the thousand pounds of steam as a starting point, rather than the amount of coal burned. The latter is such a decidedly variable quantity as it depends on the kind of coal, whether it is lump or duff, mine run, or any other size, also depending upon the quality of coal coming from one mine as varying from that of another mine, the rate of combustion on the grates and the type of grate and the type of boiler, the moisture of the coal—all those things are elements which enter into and change the problem, and in some cases the rates of combustion and other features in the boiler room change the coal used per horse-power hour, so much so that the efficiency of one machine over the other was entirely overcome, and the balance thrown to the other side by these matters in the boiler room; whereas, if you take it from the steam used in lifting to the pump, you will have that feature eliminated, the 1,000 lbs. of dry steam at a given pressure being a definite calculable quantity.

President Johnston: I think Mr. Windett's remarks are very much to the point, in determining the efficiency of pumping machines and other machines as well.

Discussion by C. W. Melcher, Mem. W. S. E.

Mr. Chairman:—There is something about the diagram, which Mr. Johnson designates as Fig. 91, which strikes me as peculiar, and that is the fact that all of the curves appear to originate from a different point. According to my notion, they should all pass through the zero point of lift, as at that point there is certainly no work to be done and no theoretical or actual power to be exerted.

According to this diagram, it takes about 6 H. P. for 1,000 gallons of water to flow out of a well of its own accord at the surface, and it looks as though the writer may have taken two points from tests made and drawn a curve through those points, without reference to a point of origin. It is possible that the character of the curve may change somewhat as it nears the zero point of lift, but, in any event, it should pass through that point.

Mr. Melcher:- President Johnston in his discussion refers to the pumping plant at Riverside, where the pump is to be installed in a room excavated 150 feet below the surface. The pumps for this work are, I am told, to be triple expansion and are expected to develop a horse-power on 30 pounds of water per hour. If there same pumps were located at the surface and used for high service duty only, and a Corliss Compound Condensing Air Compressor used to deliver the water from the wells into a cistern at the surface, the amount of steam used by this compressor should not be more than 17 pounds per indicated horse-power per hour. This would show a saving in favor of the Air Compressor of more than 40 per cent in fuel, which would, to a considerable extent, offset the losses by the Air Lift System of pumping.

If the water level in the wells is to be drawn to 150 feet below the surface to get the supply of water desired, namely, 700,000 gallons per 24 hours, the air pressure required would be from 90 to 100 pounds, and at this pressure a saving of at least 12 per cent may be effected by compressing the air in two stages, that is, compressing it in one cylinder to about 40 pounds, then passing it through an inter-cooler and reducing the temperature to that of the atmosphere, and finally compressing it in the second cylinder to the required pressure.

An additional saving may be effected by taking in cooler air into the compression cylinder. It has been found that a difference of 5 degrees in the temperature of the intake air will make a saving in coal consumption of 1 per cent. The usual temperature of an engine room is anywhere from 70 to 90 degrees Fah., while the temperature of the water in deep wells about Chicago is in the vicinity of 45 to 50 degrees. By taking the air from the top of the well after it has brought the water to the surface, it may be returned to the compressor at a temperature of probably 30 degrees below that of the engine room.

At the La Grange, Ill., water works this system of returning

the air from the well is in use. A connection is made from the well casing to a cylindrical drum, about 18″ diameter and 8 or 10 feet high. From the side of this drum the discharge from the well passes out, and from the top is led an air pipe to the intake of the air compressor. The air, after doing its work in the well, is reduced to the temperature of the water, and is returned to the compressor at fully 30 degrees lower temperature than that of the engine room. This means a saving in coal required to drive the compressor of about 6 per cent. A test was made at La Grange last summer, the plant being run on two consecutive days, the first day drawing the air from the engine room and the second day taking the air back from the well, and it was found that about 6 per cent less coal was used per gallon of water pumped when the air was returned from the well to the compressor.

A comparison of capacity between the air lift and deep well systems of pumping is shown very conclusively by results obtained by a test at Berwyn, Ill., water works. At this point two (2) 8″ wells were pumped by deep well pumps at the rate of 325,000 gallons per 24 hours, which was the most that could be obtained by this system of pumping. Last summer one of these pumps broke down, and in order to get the pump barrel out of the well it was necessary to call in an expert well driller, who was obliged to erect his derrick over the well and spend two weeks on the job before he succeeded in removing the pump barrel from the well. It was then decided to see what could be done with the air lift, and the well was piped up and a small compressor, 12″x12″ cylinder, connected with it. With this small machine a supply of water equal to 500,000 gallons per 24 hours was secured from the single well, as against 325,000 gallons by the deep well pumps from two wells, and this larger amount of water was secured by the air lift system with less coal consumption.

It is very generally conceded that the air lift will raise more water than any other system from a given size well. It also purifies the water and lowers the temperature perceptibly. When water is wanted quantity and purity cut a more important figure than efficiency, although that is worth considering. The efficiency of the air lift can be made to compare favorably with other systems when pumping the same quantity of water and under exactly similar conditions.

Remarks by President Johnston.

I would like to make a response to one or two remarks that were made this evening. Mr. Nagle, in drawing a comparison, or rather in describing the performance of the Pohle air lift for securing a large supply of water from a well, took a case in which they got three times as much water from a given well with a Pohle air lift as he would with a deep well pump, and concluded

therefore that, in order to get as much water, it would take three wells with deep well pumps. That conclusion is not correct in my mind. You may enlarge the upper portion of a well and put in a deep well pump.

If in boring wells the style of pump to be put in the wells was held in mind at first, the upper portion of the well to the proper depths might be made large enough to take a deep well pump of almost any size and of good economy, if the principles followed by Mr. Johnson are adhered to.

Mr. Lewis, in the course of his remarks, made a claim, if I did not misunderstand him, that they were getting quite as good results in economy with the air lift as with other types of machinery used in deep well pumping. This I can hardly agree with. At Memphis, Tenn., there is an example of deep well pumping that is perhaps larger than usual. In ordinary work, with Kentucky coal, they get about seventy million foot-pounds duty, which corresponds to about 100,000,000 pound duty per 1,000 lbs. of steam. From recent guarantees made by the air lift people, they have been willing to guarantee less than twenty million foot-pound duty.

The annual bill for coal at Memphis is now $8,000, with the air lift it would therefore be $40,000.

As to Mr. Lewis' statement that the air lift is very satisfactory wherever applied, that may all be so, and yet the air lift not be the best pump.

Mr. Melcher in his remarks with regard to the Riverside pump made the correct statement that there would be a triple expansion pump at the base of the shaft to pump the water from the base of the shaft and that would give an indicated horse-power with about 30 pounds of water. He says that an air compressor at the surface of the ground, a good type air compressor, would give an indicated horse-power for two-thirds of the amount of water. That is very true, but it does not mean that the air lift will pump the same water with two-thirds of the same amount of coal. The fact is that the triple expansion pump is guaranteed to develop seventy-five million foot-pounds duty for each 1,000 pounds of steam, while the air lift people will guarantee less than 20,000,000 duty. The air lift will require more coal to do the same work than will the pump that is designed for the work in the ratio of 75 to 20—something over three and one-half times as much as coal. Mr. Melcher omitted to compare the losses between the indicated horse-power and useful horse-power in the pumping the water in both cases.

Discussion by C. C. STOWELL, Mem. W. S. E.

Mr. Chairman: I do not know that I can add much to what has already been said. Possibly a little data of the matter at Rockford might be of interest. We have nine wells; five of them are what we term deep wells because they penetrate the Potsdam rock and are from 1,300 to 2,000 feet deep.

At the time the test was made of these wells, of which Mr. Mead has spoken, they were flowing in the neighborhood of 1,200,-000 gallons per 24 hours, and the flow is about the same at the present time.

The shallow wells, or St. Peters, as they are known to us, because they derive their supply of water from the St. Peters sandstone, are a little less than 500 feet deep. They do not flow, the normal head being 6 feet below the level of the ground and 5 feet above the surface of the river, near which they are situated.

It was in the four (4) St. Peters wells that the Air Lift pump was worked during the 24 hour test referred to in Mr. Johnson's paper.

The first introduction of the air lift to Rockford was in Sept., 1893, by agents of the Pohle Air Lift Co., to test the capacity of the wells.

It was first put on the best flowing well. Experiments were made with different sizes and lengths of air and discharge pipes, discharge openings in the air pipe and in the number of revolutions of the compressor.

The compressor was small and an old portable boiler was used, so that no attempt at economy was made.

The question was the amount of water that could be obtained from the wells.

It has been the question of more pure water for the city for several years.

In October, 1893, tests were made of one of the St. Peters wells, while deep well pumps of the ordinary type were being used in the remaining three.

Shortly after these tests a contract was entered into with the agents of the Pohle Air Lift Pump, to furnish two million (2,000,-000) gallons of water from the four (4) St. Peters wells and discharge it into the reservoir or reduce the water in the wells below eighty-five (85) feet from the surface of the ground. All was to be completed for the test by June 1st, 1894.

Up to December, 1895, the contract had not been carried out; the quantity of water had not been obtained and but three wells had been successfully operated at the same time, although numerous devices had been used to obtain the result.

The Rand Drill Co., being interested, having furnished the compressor, and the agent for the Pohle Air Lift Pump, Mr. Alexander E. Schuee, having died, our Mr. J. F. Lewis undertook a settlement with the city, and virtually made a new contract, the substance of which was that the city should pay for the plant in proportion to the amount of water obtained on a twenty-four (24) hour test.

This was made in Feby., 1896, and is the one referred to in the paper under discussion.

One point in the tabulated data of the test to which I wish to call attention, and which I believe has not been brought out be-

fore, is that the head was not the same in all the wells, which would indicate that more water was obtained from one than from another, and therefore would affect the result in calculating the efficiency of the pump.

So far as we were able to judge, the one lowered the least yielded the most water, the other three (3) about equal quantities.

I intended to make some tests to ascertain the quantity delivered from each well when the heads were reduced, as they were during these tests, but it was necessary to provide for more water as soon as possible, hence the idea was abandoned.

A thermometer held in the air as it escaped from the wells showed it to be from one to three degrees lower than the water discharged from the same well. The temperature of the water was 54 degrees.

To obtain the greatest quantity of water at the least expense, with the material at hand, I reduced the lift for the Air Pump about sixteen (16) feet and filled the reservoir by connecting it with the distributing mains.

I also connected three (3) of the deep wells with the air, using one and one-half (1½) and one and one-quarter (1¼) inch air pipe, with discharge opening the full size of pipe in the well and the eight (8) inch casing for discharge pipe.

It was found difficult to control the supply of air to each well by valves placed near the receiver, and in making the changes I placed them at the wells and used a large air main which gave greater storage for the air.

The coal bill has been reduced by these changes about one dollar ($1.00) per million gallons pumped.

The steam from the boilers is used for running the compressor, the high duty pumps and supplying the jackets of the idle pumps.

The engineer's report for last month showed 86,624,000 gallons pumped into the mains, at a cost of 255½ tons of coal, the coal being New Kentucky screenings.

Discussion by C. F. Loweth.

As a result of first experience, we were led to believe that a deep well pump was a good thing to avoid, and each succeeding experience has confirmed this. We have on several occasions placed a force pump in a deep well pit, as an alternative to a deep well pump, but not always without doubt as to the wisdom of our choice. We therefore congratulate the author for the new form of pump he has perfected, and from which so much may be expected.

Undoubtedly the substitution of a power head, driven by a gasoline or some other motor, in place of a steam cylinder directly connected to the well cylinder, is economical and otherwise desirable.

We had been responsible for the installation of one air lift pumping plant. While no complete test for efficiency was made, the operation of the plant was to some extent a disappointment; it was probably as efficient as a common form of deep well pump would have been, but more had been expected. The cheapest and least efficient form of steam driven air compressor was used, and it was a matter of regret that this had been substituted for a power compressor driven from a compound engine used for other purposes, which was the arrangement first planned but abandoned for considerations of space.

The author's double plunger deep well pump has one of the advantages of the air lift pump, viz.: in raising a larger supply from a given well than is possible with the common form of pump. This is often a great consideration, especially where the well is expensive, and was in the instance just referred to where the use of a common pump would have involved practically continuous pumping, day and night, and at thepresent time, when the use of water has largely increased, would require an additional well, with its own pumping machinery, necessarily located at some distance from the central pumping station.

For the air lift pump it may be claimed that it is not liable to stoppage or breakage from sand, and that all working parts are above ground and readily accessible. The removal of a deep well cylinder, a not infrequent occurrence, is a task of no small proportions.

CLOSURE.

By E. E. Johnson, Mem. W. S. E.

The author is deeply indebted to the gentlemen who have, by their discussions, added so much of valuable data to the subject under consideration. It is to be regretted, however, that Mr. Lewis and Mr. Melcher in maintaining the superiority of the special type of pneumatic pump known as the air lift should have confined themselves to an ounce of fact added to a pound of assertion in defining the possibilities and limitations of the system. No repairs, more water, purification of the supply, and favorable economy compared with other methods are claimed.

Pumping by machinery of any kind necessitates repairs, the amount and cost being determined by the kind of machinery and the character of the construction, first-class machinery of all types requiring less to maintain.

As to the matter of obtaining more water, in wells of small diameter this is true, but there is no reason why the full amount the well is capable of supplying cannot be drawn therefrom by any of the other methods. It is a matter of designing the well. The time has passed when anything that is a hole in the ground

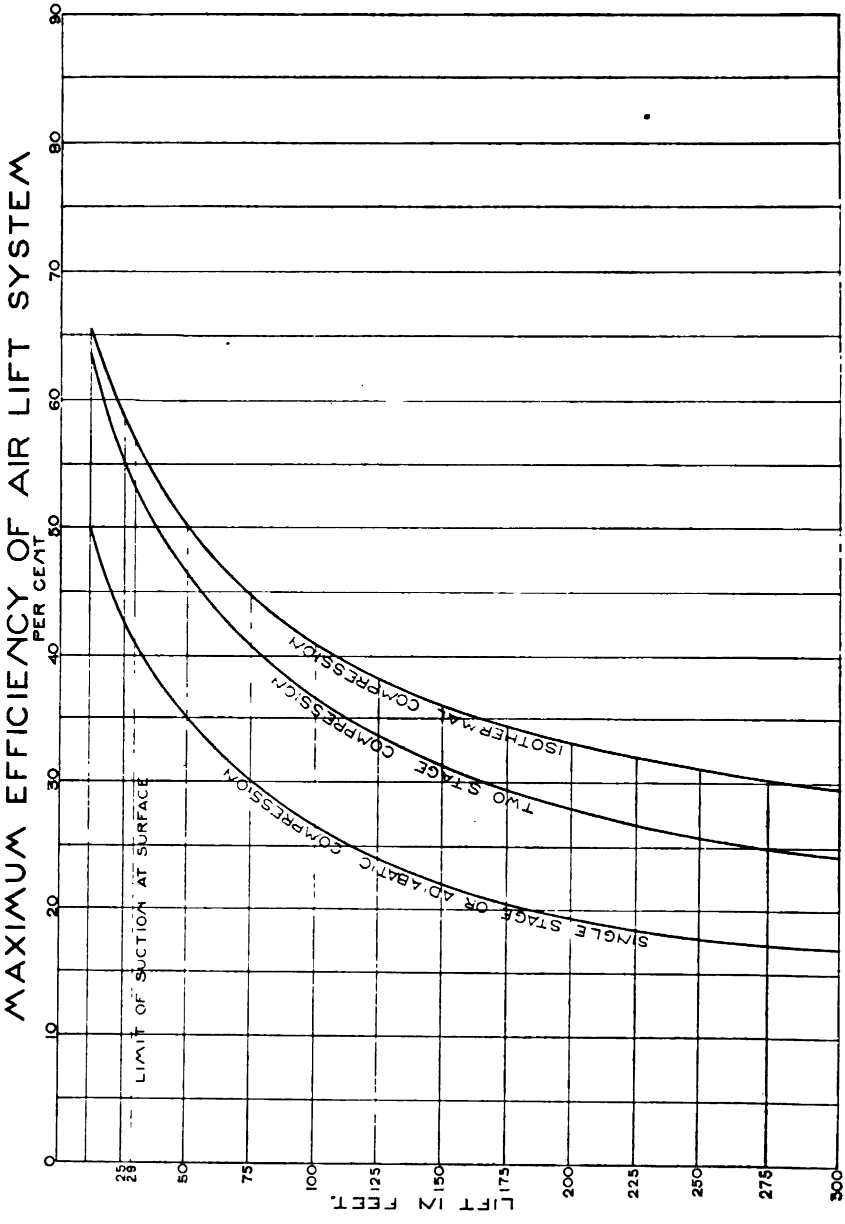

MAXIMUM EFFICIENCY OF AIR LIFT SYSTEM
PER CENT
0
10
20
30
40
50
60
70
80
90
LIMIT OF SUCTION AT SURFACE
ISOTHERMAL COMPRESSION
TWO STAGE COMPRESSION
SINGLE STAGE OR ADIABATIC COMPRESSION
25
29
50
75
100
125
150
175
200
225
250
275
300
LIFT IN FEET.

Fig. 118.

TABLE XI.

TABLE 1						TABLE 2					TABLE 3											
LIFT IN		THEORETICAL HORSE POWER				EFFICIENCY OF AIR LIFT					MAXIMUM DUTY OBTAINABLE WITH AIR LIFT. WATER ECONOMY OF COMPRESSOR ENGINE.										LIFT IN	
			TO DELIVER ONE CUBIC FOOT OF AIR PER MIN			THEORETICAL			TOTAL FROM POWER APPLIED TO WATER DEL.		TWO STAGE			SINGLE STAGE								
LBS. PRESS	FEET HEAD	TO LIFT ONE CUBIC FOOT OF WATER PER MIN.	ISOTHERMAL	TWO STAGE	ADIABATIC	ISOTHERMAL COMPRESSION	TWO STAGE COMPRESSION	SINGLE STAGE OR ADIABATIC COMPRESSION	TWO STAGE COMPRESSION	SINGLE STAGE OR ADIABATIC COMPRESSION	20 LBS	25 LBS.	30 LBS.	20 LBS.	25 LBS.	30 LBS.	35 LBS.	40 LBS.	45 LBS.	50 LBS.	FEET HEAD	LBS. PRESS.
5	11.54	.02185	.02514	.02572	.0263	.87	.848	.83	.623	.497	61.6	49.3	41.1	49.2	39.3	32.7	28.1	24.6	21.8	19.7	11.54	5
10	23.09	.04363	.05586	.05992	.064	.78	.728	.684	.546	.41	54.2	43.3	36.2	40.6	32.5	27.	23.2	20.3	18.1	16.3	23.09	10
15	34.63	.06545	.09105	.0962	.1015	.72	.687	.648	.515	.389	51.	40.7	34.	38.6	30.8	25.6	22.	19.3	17.1	15.4	34.63	15
20	46.20	.08727	.12994	.1391	.1483	.675	.627	.59	.47	.354	46.5	37.2	31.	35.	28.	23.3	20.	17.5	15.6	14.	46.20	20
25	57.75	.109	.17191	.1897	.2004	.635	.575	.545	.432	.327	42.7	34.2	28.5	32.4	25.9	21.6	18.5	16.2	14.4	13.	57.75	25
30	69.31	.13091	.21678	.2370	.2573	.603	.548	.508	.412	.305	40.7	32.6	27.1	30.2	24.2	20.1	17.3	15.1	13.4	12.1	69.31	30
35	80.86	.1527	.26445	.2915	.3187	.577	.52	.478	.39	.287	38.6	30.8	25.7	28.4	22.7	18.9	16.2	14.2	12.6	11.4	80.86	35
40	92.41	.17454	.31375	.3489	.3842	.557	.502	.455	.376	.273	37.2	29.8	24.8	27.1	21.7	18.1	15.5	13.5	12.1	10.8	92.41	40
45	103.90	.1963	.36368	.4085	.4535	.540	.482	.433	.362	.260	35.8	28.6	23.9	25.8	20.6	17.2	14.7	13.	11.5	10.3	103.90	45
50	115.50	.21818	.41848	.4722	.5261	.522	.464	.415	.348	.249	34.5	27.6	23.	24.7	19.7	16.4	14.1	12.4	11.	9.9	115.50	50
55	127.00	.24	.47112	.5366	.6023	.51	.447	.40	.336	.24	33.2	26.6	22.1	23.8	19.	15.8	13.6	11.8	10.6	9.56	127.00	55
60	138.60	.26181	.52855	.6051	.6818	.495	.432	.384	.324	.231	32.	25.6	21.3	22.9	18.5	15.3	13.2	11.5	10.2	9.15	138.60	60
65	150.10	.2836	.58612	.6734	.7608	.483	.422	.372	.316	.223	31.3	25.	20.9	22.1	17.7	14.7	12.6	11.1	9.85	8.85	150.10	65
70	161.70	.30545	.64812	.748	.8483	.471	.408	.36	.307	.216	30.4	24.3	20.2	21.4	17.1	14.3	12.2	10.7	9.5	8.55	161.70	70
75	173.30	.3273	.70952	.823	.9380	.462	.398	.35	.299	.210	29.6	23.9	19.9	20.8	16.7	13.9	11.9	10.4	9.25	8.32	173.30	75
80	184.80	.3491	.76843	.898	1.0291	.455	.39	.343	.292	.206	28.9	23.1	19.3	20.4	16.3	13.6	11.6	10.2	9.05	8.15	184.80	80
85	196.30	.37	.83039	.976	1.1231	.446	.38	.331	.285	.198	28.2	22.6	18.8	19.6	15.7	13.1	11.2	9.8	8.7	7.85	196.30	85
90	207.90	.3927	.89444	1.055	1.2176	.439	.373	.324	.28	.194	27.7	22.2	18.4	19.2	15.4	12.8	11.	9.6	8.52	7.65	207.90	90
95	219.40	.4145	.96164	1.137	1.3148	.431	.368	.315	.276	.189	27.3	21.8	18.2	18.7	14.9	12.5	10.7	9.35	8.3	7.5	219.40	95
100	230.90	.43636	1.0243	1.247	1.4171	.428	.352	.308	.264	.185	26.1	20.9	17.4	18.3	14.6	12.2	10.5	9.2	8.15	7.3	230.90	100
110	254.10	.48	1.162	1.394	1.626	.413	.346	.296	.26	.177	25.7	20.6	17.1	17.5	14.	11.7	10.	8.75	7.76	7.	254.10	110
120	277.20	.5236	1.301	1.571	1.841	.402	.333	.285	.25	.171	24.8	19.9	16.5	16.9	13.5	11.3	9.65	8.45	7.5	6.75	277.20	120
130	300.40	.5675	1.443	1.755	2.068	.394	.324	.275	.243	.165	24.1	19.3	16.1	16.3	13.1	10.9	9.3	8.2	7.25	6.5	300.40	130
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	2	1

is a good artesian well, and as much careful thought must be put in the determination of the proper size of the different diameters of the well bore as into the pumping machinery, if final close economy in operation is sought.

Aeration of water has been a matter of contention among engineers in the consideration of surface supplies, but the very weightiest reason for developing deep subterranean supplies lies in their freedom from contamination. It would seem, therefore, that possibilties of purification of such waters in the pumping process is superfluous.

The economy of operation of any system of pumping is one of the final tests of its fitness, and vague hints of improvements yet to come do not touch the vital part of the case in the pneumatic process. In order to sift the two grains of wheat from the two bushels of chaff it will be necessary to get at some fundamental facts which in the foregoing discussion have not been brought out.

The air lift pump operates by displacement of a volume of water by an equal volume of air, which is expelled from the air pipe into the discharge pipe of the well. A submergence of slightly more than the lift having been found best adapted by its more economical use of air. If, therefore, we compare the theoretical horse-power required to lift water with the theoretical horse-power to deliver an equal volume of air at under equivalent pressure by isothermal, two stage and adiabatic compression, we shall have the maximum "theoretical efficiency" attainable for the air lift mechanism, considering both the compressing and pumping processes to have efficiencies of 100 per cent.

For the practical efficiency of the air lift we must take into account the compressor efficiency which is dealt with quite fully in the body of this paper, with 55 per cent as a fair average for single stage compression. To be just, we will assume 60 per cent for single stage compression and 75 per cent for two stage compression, figures that approximate closely the results given by Prof. W. C. Unwin for the large compressors in use on the Paris compressed air transmission system. The pumping process cannot in practice attain to 100 per cent efficiency, but as it is impossible to give a good approximation from any data available, we will assume it as 100 per cent in the tabulation. The resultand total efficiency then from power applied to water delivered will be somewhat greater than can be secured in practice. As will be seen from the table XI and diagram Fig. 118, this efficiency varies widely with the depth of lift.

The consideration of the problem so far is independent of the cost of producing the power in the compressor engine, and to avoid any possibility of error in assuming such cost the author has tabulated the duty obtainable in single and two stage compression for a sufficient range of engine economies to meet any probable guarantees by builders of compressing machinery. The

duty is given in millions of foot-pounds per 1,000 pounds of dry steam supplied. The more complete analysis of the problem has necessitated the redrawing of Fig. 91, which appears in the body of the paper, and from which the actual horse-power to deliver water from any depth may be found. At "A" is plotted the result of the Rockford test with 85 foot lift referred to before. It will be noted that there the actual results in the consumption of power are not so good as shown by the diagram, which proves if anything that the assumptions on which it is based err in favor of the pneumatic system.

At "B" is plotted the result of a test of a plant of the writer's design at Stockton, Ill., lifting 284 feet. It absorbs 7 H. P. per cu. ft. delivered per minute as against 3.2 H. P. and 2.2 H. P., which would under similar conditions be required by single stage and two stage air lifts respectively, and as power can be applied by one method as economically as the other in the driving engine, these figures indicate that more than 4½ times the fuel must be used to do the work by a single stage air lift, and more than three times the fuel by the two stage method than by the apparatus used. With the data given it is believed no argument is necessary to point out the relative fitness of the two classes of apparatus.

Referring to Mr. A. F. Nagle's discussion, it may be stated that the valves in the De Kalb pump are not of the ball type but are conical.

We take issue with Mr. Nagle in his statement that the pump efficiency is decreased by an increased speed, the lift remaining the same. Such has not been our experience. The following reasons may be adduced: The friction of the mechanism is a function of the intensity of bearing pressure, and within the limit of speeds, say 10 to 40 revolutions per minute, is independent of the speed. The friction loss, therefore, would be practically constant for any speed. The work from the pump varies in proportion to its speed, therefore the friction loss is a much larger factor of the total work on a slow speed than it is on a faster one. Based on this assumption, the efficiency of the Cambridge pump at its full capacity should be about 85 per cent instead of 67 per cent as at the slow speed.

Mr. Nagle is in error in quoting the paper as giving 25 strokes per minute as maximum for any deep well pump. Such is the case where the water column is stopped and started twice in each revolution of the pump, but the limit for pumps that maintain a practically constant rate of discharge will not be fixed by like conditions and will be much higher.

Mr. Melcher in his criticism of Fig. 91. neglects to take account of the fact that *theoretical powers only* find their origin at O., all others of necessity cannot.

VI.

TECHNICAL EDUCATION.

Discussed February 3, 1897.

THOS. T. JOHNSTON, PRESIDENT, IN THE CHAIR.

GENTLEMEN: Unless there is some objection, we will dispense with the regular order of proceedings for the evening, and proceed at once to the main purpose of the meeting. In our constitution it is written that "The object of this Society shall be the advancement of the science of engineering and the best interests of the profession. Among the means to be employed shall be meetings for the reading and discussion of appropriate papers and matters of engineering interest, and for professional and social intercourse." The Society is on this occasion favored with a rare opportunity to take advantage of that part of the object and means which pertain to professional and social intercourse. The Alumni of the Rensselaer Polytechnic Institute have been holding a meeting in Chicago during the past two or three days, and your Board of Direction has arranged that the President of the Rensselaer Polytechnic Institute and such of the faculty as are in the city should be received by the Society this evening, aided by the representatives from the local educational institutions; from the Chicago University and Armour Institute, Lewis Institute, Northwestern University and other institutions. Being an alumnus of the Troy School myself, and furthermore not being a great orator, I have prevailed upon Mr. Isham Randolph, past president of the Society, Chief Engineer of the Sanitary District of Chicago, to welcome our guests and to discuss the subject of the evening.

MR. ISHAM RANDOLPH.

Gentlemen, it is with very great pleasure that I extend on behalf of the Western Society of Engineers a cordial greeting to the wise men of the East who have come to visit us on this occasion. It is seldom that as many members of prominent educational institutions are gathered in an assemblage as we have here tonight. Here we have the president and the director of the Troy Polytechnic Institute, an institute which has given to Chicago and to the development of the West some of its ablest and most successful men; an institute which has sent out men to other institutions of learning to disseminate the wisdom which they have gathered within those classic walls. It is well that they should meet tonight the heads of other educational institu-

tions in this inter-oceanic zone, and I feel that we all look forward with anticipations of keen pleasure to the words of wisdom that are to be distilled from these learned lips tonight.

I am hardly the man to discuss technical education. I come from the ranks of what are known as practical men, but I have learned that the only sound practice is based upon the truest theory; the two can not be divorced. Where we practical men succeed it is because we follow out the lines of theory, sometimes not knowing it; sometimes simply as imitators of what others have done. At other times we learn by hard experience what has been taught within the walls of colleges to others. I have often felt when I have been associated with men who are equipped at every point for the contest of life, that I would have given some of the best years of my life if I could have gone through the course which has fitted them to battle so successfully in life's contest. I think that from year to year the practical man is learning more and more to appreciate the help which the scientific man is able to give him. There is no longer among us that inclination to belittle the college graduate which a few years back was far too rife in the ranks of the practical men.

Gentlemen, as I said before, I am not the man to discuss technical education, and I yield the floor to those who can give us words of wisdom which we shall carry hence and remember and appreciate in after years. I thank you. (Applause.)

BY JOHN HUDSON PECK, LL. D., PRESIDENT RENSSELAER POLYTECHNIC INSTITUTE, TROY, N. Y.

Gentlemen of the Western Society:—I am not the person from whom the words of wisdom are to fall. You may expect those from the Director of the Institute, who will appear as the instructor. I suppose it is best that I should explain to you at once that the administration of the Rensselaer Polytechnic Institute is not in the usual form. We have a president who is the executive officer under a board of trustees and a director who is the head of the faculty. The president by virtue of his office has no teaching place, although usually he gives lectures in the course according to his own particular inclination.

It so happens that I am not an engineer, that is, I was not educated as an engineer. I am very fond of meeting with them. I have met a great many of them, and I always enjoy an assemblage of engineers. There is a different expression on that audience from any other that I ever face. There is more intensity, there is more directness, it is different, I cannot explain it exactly, I cannot describe it, but it is a different expression, and it is one that I am sure any man who is up-to-date, any man who loves his country, any man who loves his fellowmen, is delighted to see on any audience of American citizens. (Applause)

Of course, in this way I become somewhat associated with and

feel almost like an engineer. Perhaps you have heard the story of the locomotive engineer on the Erie Railroad, I think it was, who ran into a siding one day and while he was waiting for the other train, after wiping off his engine and oiling the journals, leaned up against one of the drivers and saw a squaw that had come down with a little pappoose. Having nothing else to do he entered into conversation with her and said, pointing to the pappoose, "Little Injun?" "Well, no," she says, "part Injun, part inguneer." (Great laughter and applause.)

Well, that is about the condition that I find myself in. I do not know how close I am expected to get toward words of wisdom, Mr. President.

What I do wish to say on behalf of myself and of the trustees of the Rensselaer Polytechnic Institute who are present and of the members of the faculty who are here, as well as of the visiting alumni, is that we have been delighted with the hospitality that we have received in Chicago. We have been met like brothers, as we feel, and we have been shown your great engineering works in progress. I believe we have seen Chicago's "last ditch," and also some of the party have been out to see its "crib." The result is that we feel pretty well acquainted with you collectively, perhaps better acquainted than we are with you personally, but we have really enjoyed ourselves, and I desire to thank you, all of you who have taken any part in the entertainment which we have received, very cordially for what has been done.

But there is one thing more, gentlemen. I had no idea of being here tonight and I have not prepared a speech for this occasion. I say this to you because it would be discourteous for anybody to address this audience on this subject who had not prepared himself thoroughly without excusing himself. I did not know what the occasion was to be, or I should have made my arrangements to have staid when I first came.

But I have thought somewhat of this question of technical education. There seems to be an idea in some minds that there is a difference between technical education and other education. Now, what do you contrast it with, gentlemen? Of course it is developing, it is disciplining, it is informing. It answers the functions of education, but the discipline, the development, the information are different from that which is ordinarily called liberal education, meaning, as I understand it, a more general education. Technical education requires for its foundation a certain aptitude. It is not everybody that can take a first-class technical education. I have known an exceptional class of 86 young men to dwindle down to a graduating class of 12. Not because they were not able men, not because they could not take a first-class education, but because their aptitudes or their preparation, or their heredity, or whatever it was, did not suit them for that particular kind of education. They could not take it. They did not have the develop ment, they did not have, perhaps, the intensity that is necessary;

they did not have the directness, the thoroughness, the exactness that is required for what is called technical education, as I use the term. So that I should say the difference is one of degree. But it is said technical education really is driven only towards a particular point. If we fit a man to be a civil engineer, he is a civil engineer and that is all, because it is a professional engineering school. If we fit a man to be an architect he is an architect and that is all, because it is an architectural school. I am not sure that that may not be said of some kinds of technical education. I am not here to oppose any views that others have, but I will state to you what our view always has been at Troy. We give one engineering degree, we call it civil engineer. We call it civil engineer, not to distinguish it from municipal engineer, not to distinguish it from mechanical engineer or sanitary, or any other kind of special engineer, we use civil engineer as it was originally used, to distinguish the degree from military engineer. We give a young man graduating from our school the degree of civil engineer, and we mean by that that he is grounded in general engineering. We mean that with the fit we give him he can go out into the world just as a doctor goes out from a school of medicine, just as a lawyer goes out from a school of law. The latter does not go as an advocate or as a real estate lawyer, or patent lawyer, or anything of that kind, he goes out as a lawyer and he looks around for clients. Perhaps his friends introduce him to men that have a real estate business and then he becomes a real estate lawyer; perhaps his own peculiar qualifications recommend him to some inventors and he becomes a patent lawyer, or he drifts to a special line of work, whatever it may be, according to his special opportunities as well as his special aptitude. So a young man going out from a law school has more chance, as you see, than as if he fitted himself for any particular branch of the profession. In the same way we treat engineering. We think that our young men can accommodate themselves to these various branches of engineering within a very short time after their graduation. We know that we can go into any of our large cities and find engineers from our school in almost every branch of engineering. They have drifted into those various places. They have found places simply because they were ready for them; they were ready for things of which they had no idea when they entered the institute. Now let me give you some illustrations.

We publish, as most technical schools do (I think we began it originally), the name of every graduate in every register of the institute. We not only do that, but we keep it up. We follow it up every year so far as alumni will let us know; if there has been any changes in their business we make changes in the register. So that every young man going out from the Institute knows what every other man is doing and has been doing, and the public knows or may know it equally well and in that way we have a business biography of every man that has ever gone out of the school.

Take Mr. Roberts, who has recently died, President of the Pennsylvania System. There was a man who had comparatively no opportunity at all when he left the Institute. He went out as a rod-man and later went into the shops; from there he became master of motive power, I believe. This was very different from the ordinary conception of civil engineering. Preparation for such a place is not included in the curriculum that leads to that degree in a great many schools. Then he came into an administrative office and he grew to be the administrator of the greatest railroad system in the world, and so administered it indirectly and directly for many years that it arrived at that pre-eminence. Yet President Roberts graduated with the C. E. degree.

Then I might take you down to New York and introduce you to a Supreme Court Judge who had no academic degree of liberal education, but whose degree is "civil engineer" in technical education. I can take you into leading banks of many of the cities and introduce you to their presidents and executive officers whose degree is "civil engineer." I can take you into the great work shops of mechanical, electrical and manufacturing companies and introduce you to their superintendents and managers whose degree is "civil engineer." It is a different idea from the construction frequently put upon the degree of civil engineer where it is differentiated from other engineering degrees. I am sorry that it is so. I think it would have been better if our degree or the other degree could have been distinctly named so that the public and the profession might recognize at once the character of the fit leading up to them. There should not be such a difference as there is in the qualifications required for the degree of civil engineer. It is about as bad as the word doctor. You cannot tell whether a man who is called "doctor" treats horses or human beings or gathers herbs or preaches to congregations. I think it would have been better if the title could have been arranged at some time in some way so that it would have had special meanings.

I have only gone into this little statement for the purpose of showing you that in dealing with this degree we have reached a point where we can consider our alumni more fairly in determining the effect of technical education than we could if we were dividing up our degree so that it would not resemble in any measure the degree of Bachelor of Arts that is given by Liberal Colleges. I think the comparison might be made very interesting.

Of course, the great bulk of our graduates start off as civil engineers, but they drift into all kinds of business and into all kinds of administrative places, just as the graduates of colleges. They do it in a different way, they are different looking men and as a rule they are a different quality of men. There is an intensity, as I said before, which is a different kind of intensity; an intelligence which is a different kind of intelligence; a business capacity which is more exact, more thorough I think than that

which comes from the more general training of the liberal schools. I think any person who will take the register of the Institute and compare technical education as it is exhibited there, with liberal education, as I suppose this subject of discussion is to be compared, will find that the comparison is very gratifying to technical men. I do not say that it is better, it is different. It certainly is a splendid showing, when you can find men from a technical school succeeding, growing up from one position to another in financial institutions, in manufacturing institutions, in mercantile places and in law offices and in the pulpit and in divinity schools and in railroad management. I cannot begin to tell you where they all are, there is hardly a walk of life where they are not—I do not know of any poet, I do not know of any novelists. We are not literary. There may be that distinction, that the culture which we give in the technical schools is different in that effect. I think as a general rule the engineering mind, the mind that has aptitude for that kind of excellence and eminence is not of the kind that would succeed best in ordinary literary work. But technical men make splendid editors. They can weigh up people and measure facts just as well as any set of men I know. But this is a very cursory view of the position a technical school in the educational world and without any statistics, which I have and which I would have brought with me if I had supposed that I would have been called upon on such an occasion as this. I can only give you the proposition and if you are at all interested to know what relation technical education bears to what is ordinarily called liberal education, send to me for a register of the Institute and learn what technical men are doing. (Applause.)

BY PROF. PALMER C. RICKETTS, DIRECTOR RENSSELAER INSTITUTE.

Mr. President and Gentlemen of the Western Society of Engineers: The courteous invitation of your society to members of the Alumni Association of the Rensselaer Polytechnic Institute is fully appreciated by at least one graduate of that school, so much so that at a very busy time he has delayed his departure for a day to be present and get the benefit of this discussion by engineers whose works surely prove that their technical education, wherever received or however acquired, has not been neglected. Before such a society, technical education of course means engineering education, and even thus restricted its scope is so wide that one would hardly know where to begin or where to end if he were to express his views as to details and methods. I came here to listen and to learn. I shall simply outline, in the fewest possible words, one or two general requirements which in my opinion are essential in an engineering education.

Engineering is a profession, not a trade. Most of the work of an engineer is head work, not hand work. One must, however, learn the use of tools for head work not less than for hand work.

This brings us to the first requirement: That the student of engineering, in the schools or out of them, should obtain a solid fundamental, theoretic, mathematical groundwork. Such principles are his tools. He must know how to use them. Without them he is as helpless as the stone-cutter without his chisel or his point.

I have spoken of head work as distinct from hand work; of the profession of the engineer as distinct from the trade of the mechanic. To most young men hand work is easier than head work. To no one is this more apparent than to an instructor in an engineering school. The general tendency is to do the hand work at the expense of the head work. The more of the former in a curriculum the more nearly you approach the education of the mechanic. I believe, therefore, that work in the shop and laboratory should be so limited as not to trench to a great extent upon the time properly given to theory. Shops or laboratories are useful adjuncts and should be maintained, but they should be used with great discretion.

Modern business competition tends to produce mechanics who, before they have had an opportunity to learn the use of all or most of the tools of their trade, are put to work and kept on special machines. The cost of production is thus lowered, but so is the probability of future advancement of the mechanic. Early specialization produces the same effect upon the student of engineering as upon the apprentice; the same effect upon the engineer as upon the mechanic.

Another requirement, therefore, is a broad foundation in the principles of engineering. It is true that the field of work of the engineer is constantly broadening, but it is also true that few men, indeed, are able to closely confine themselves to one narrow branch of professional work. And no one can so confine himself with the best results until he has had more or less extended experience in allied branches. He makes the best specialist who has not always been one. The broad education, the capacity to take the general view, counts in this as in all other fields of labor. How then can a system of engineering education be defended which begins by confining a youth of the schools within limits so narrow that even the specialist, after a broad, practical training, must reach beyond them in his daily work? Must not the hydraulic engineer know, at least, the principles both of structural design and of steam engineering? Should not the bridge engineer be versed in the principles of hydraulics?

I believe it to be wrong in principle to specialize too much in the schools; to subdivide the curriculum, as is sometimes done, so that eight or ten different courses are given in an attempt to educate young men for various branches of the profession. I would recognize three different courses, and three only. One would cover what is now generally understood by the term Civil Engineering, one Mechanical Engineering and the third Mining

Engineering. The time allowed for an engineering course is so limited and these three branches of the engineering profession are not so nearly allied as to make it irrational to specialize to this extent. It is irrational, I believe, to again subdivide each of these branches into several others. What is a railroad engineer? Should he not be a civil engineer in its broadest sense? What is an electrical engineer? If he is not a mechanical engineer, what is he? And what kind of a course in mechanical engineering today would that be in which provision was not made for extended study of electrical appliances?

It is, of course, easy to see why this subdivision has arisen in some schools. The time is limited. Why not do one thing well instead of trying to do too many things not so well? Why not give so much practical as well as theoretical instruction in one speciality that the graduate of the school will be well equipped to enter his special branch of the profession and thus have the advantage of one whose education has been more general and who has, therefore, not had the time to become as expert in the details of any one subject.

Possibly at first such specialization does give the young man a temporary advantage if he happen to be able to secure an immediate opening in the branch for which he has been specially fitted. But any graduate of an engineering school knows well that most young men are unable to choose what they will take but must take what they can get, and the one with the more general education will have a wider range within which his services will probably be useful.

Although this is a practical view, it is the lower one. The higher one is that although the capacity of the average man to do many things well is limited, the capacity to do one thing well is a direct function of his general knowledge and intelligence and when the conditions confronting, not only the engineer in general practice, but even the specialist, are such that the one thing always means a collection of correlated things the wisdom of a not too special preparation becomes manifest.

The practice in another profession, existing before ours was recognized, and in which specialization has been carried to as great an extreme as perhaps in any other, tends to confirm the truth of these remarks. Much thought by strong minds has evidently been given to the proper education of the physician, yet the courses in the schools are the same for all. What kind of an oculist would he be who from the beginning of his medical course had confined himself to a study of the eye?

As a nation we have had to struggle long with the forces of nature. We are told that we are nothing if not practical. And if there were nothing to prove this but the reception by the average citizen of the shibboleth "practical education," the case would be made. Within the four years allowed you may make a quite practical surveyor or mechanic, but you cannot make a prac-

tical engineer. Do not misunderstand me. Error in either direction may be made. Too much theory may be given. Engineers have to deal with three dimensional space, they need not bother about nth. Although the groundwork should be theoretic, illustrations should be drawn from and applications made to work which is not only practical, but which exhibits the latest and best practice. Especially should instructors in applied branches be in close contact with practical work so that they may not waste time on theoretic by-paths but give essentials leading directly toward the future work of the student. No loss in mathematical training will thus result. On the contrary, the fundamental principles will become all the more fixed. A purely theoretic establishment of a law of internal stress takes a new meaning if the student has pulled apart, in the testing machine, a piece of mild steel or crushed a short cast iron column and examined the angles of rupture.

My ideas of the extent to which theory may properly be supplemented will be indicated by a few examples from the practice of a school of civil engineering with which I am familiar. After a course in the theory of structures has been given, each student designs a bridge and carries it through the successive stages to the shop blue print. Visits to existing bridges and to a bridge shop are made. Actual weir measurements by the use of a weir set up each year in a neighboring stream illustrate the use of weir formulae and stream velocities are measured by the current meter. The resistance of materials is practically shown by the use of the testing machine; tensile and shearing tests are made, the coefficient of elasticity determined by micrometric measurements and the ultimate stress in the extreme fiber of a beam obtained by applying the result of experiment to the theoretic formula. The student becomes familiar with the use of modern surveying instruments by work in the field; in railroading a suitable place is chosen within a radius of fifty miles and a preliminary survey is made. In steam engineering indicator cards are taken and read. Gold and silver ores are assayed. In the course in metallurgy neighboring iron and steel plants are visited.

But no time is wasted in continuous use of laboratories. Only a sufficient amount of illustrative work is given to fix principles; it is not pretended that experts are thus made. It is not believed that practical engineers thus result. You cannot make them in the schools. The most practical professional education is that which forms the groundwork for the highest future professional success. We, of the schools, should aim toward this end. In any case we can not make engineers. We can only lay the foundation and we must leave the superstructure, gentlemen of the Society of Western Engineers, to you and such as you. Willy-nilly, you must complete our work—you are makers of the engineer.

Mr. Randolph: I would like to ask Mr. Ricketts a question.

This question of technical education is a very pressing one with a great many fathers. In discussing this with Prof. Judson on one occasion and telling him I had boys about whose education I was very much concerned, and I found neither one of my boys was inclined to engineering, I said my idea was that I should first give him a good mathematical education and then put him into training at practical work for a while and then have him take a course in a technical school. The Professor told me that my idea was all wrong and that I ought not to do such a thing. I would like your views.

Prof. Ricketts: I should say in a general way you are correct, because I have found by experience that we get the best results from those students that do not come too young and who have had possibly to struggle and work hard and save up money in engineering or out of it to partly or wholly educate themselves and who have not had a technical education, but when they come under those circumstances they are more likely to be earnest and capable students. I am inclined to think—I am sure I do not want to state absolutely whether you are right or wrong and I have thought a good while and very often on that subject—I am inclined to think you are correct.

DR. HENRY WADE ROGERS, PRESIDENT NORTHWESTERN UNIVERSITY, EVANSTON, ILL.

Gentlemen, two months ago a Britisher landed in the city of New York. He belonged to that class of men that come over to this country to leave their ideas with us and take away our surplus. Some of the rich citizens of New York gave him a banquet and he was called on for a speech and commenced by saying that he felt like getting beneath the table. There is not a table big enough here for me to get under, but I feel very much as he did, because I must confess to you that this being called upon to address you is a total surprise to me. I had not the slighest intimation that there was to be any discussion here or that I was expected to say anything. I was invited to dine with the gentlemen from Troy and I did not come to make a speech. I say this by way of explanation because I feel, as Mr. Peck expressed it, that it is discourteous to stand before gentlemen like you and undertake to discuss this question without having made proper preparation to do so. And let me say that I never regretted so much as I do tonight that I am not a graduate of this Troy school, because as I listened to the admirable remarks of Mr. Peck and discovered how the graduates of that institution are fitted for all sorts of things, filling pulpits and conducting banks and editing newspapers and I do not know what not, I thought that if only I had graduated from that Institution I might be able to talk here tonight on the subject of technical education. But as it is, I must confess that I am not even like that papoose

that he told you about. (Laughter.) And then, don't you know, if I had only graduated from that institution I might have that splendid expression that he talked to you about.

I feel like acting upon the advice that I heard was given to a gentleman, who was called upon to speak, when he said to a friend of his: "I do not know what to talk about, what would you talk about?" And this friend advised him to just talk about a minute. (Laughter.)

But I would like to say this in seriousness. It seems to me that it would be difficult to over-eulogize the professions which you represent. The material greatness of this country and of all the countries of our western civilization depends so largely upon you. If it were possible to obliterate, to destroy the knowledge which is possessed and results accomplished by our mining engineers, our electrical engineers, our civil engineers, our sanitary engineers, the civilization of the Western Nations would be very different from what it is, so splendid have been your achievements. This last great achievement of the engineers by which they have harnessed Niagara Falls and are transmitting its power to the manufacturing industries of Buffalo is simply one illustration of many which might be cited, showing that the future development of our country and of the countries of the world, the material greatness of these nations rests upon knowledge which men of your profession possess.

And for that reason it seems to me that these schools of technology which are being established and which have been established deserve the fostering care of all thoughtful and generous men.

As I review the history of the educational institutions in this country for the last quarter of a century, it seems to me that the greatest progress which has been made along educational lines is in the increased attention paid to technical education. I have not been out of college so very long, graduating in 1874, but at that time the universities of this country were doing very little in the way of technical education; the great technical schools had not been thoroughly developed. We are teaching mathematics and Greek and Latin and history much as we have always taught them, but the most noticeable progress in education has been made along the line of technology.

There is no technical school connected with our university. I wish there was. The two universities in Chicago are anxious for the development in connection with them of this very work which you represent and with which we have not been able to do anything. Not because we do not want it, not because we do not realize the importance of this education, but simply because we have not had the money to do it with, and you know as well as I know that the most expensive, the most costly work that the universities can engage in is just this very work. And if I may go back a moment to the thought which I expressed before, it would be

to call to your minds the fact that the English nation was brought to realize that its greatness as a manufacturing nation depended on the schools of technology. The first world's exposition that was held in London demonstrated that fact to the satisfaction of Englishmen, and we find them appointing commissions under the authority of the Queen and sending their men abroad to Germany and France to study the great schools of technology there because they were convinced that their supremacy as a manufacturing nation depended upon the better development of their schools of technology. After the Paris Exposition we find another commission appointed by Great Britain with the same end in view, the improvement of their schools of technology, and that is just what we need in this country. We do not need more colleges, we do not need more universities, but we do need more schools, more technical schools, trade schools if you please, schools of technology.

Before I take my seat I should like to say, because it may interest the wise men from the East to know, that while we have not yet any great schools of technology out here in Chicago, that after all Chicago is getting to be something of an educational center, not for the training of engineers, but for instance, for the training of theologians. This is supposed in the East to be a very wicked place, and I do not stand here to deny that it is. But it is also a very Godly place, and you may be glad to know that we hope to change the wickedness of this town and that we are doing the best we can to bring that end about by training theologians. There are more theological students here in Chicago than in any other place in the world. (Applause.)

You have been down to see the drainage ditch that we are digging and you hear something about the unhealthful condition of our water and all that. We are trying to counteract the evil effects of our sanitary condition and the impurities of our water by training doctors, educating them, and we are educating more doctors than any place in the United States. Three or four years ago Chicago stood third in respect to medical education, New York and Philadelphia led us, but the fact is that today there are more medical students here in this city than in any city in America. A few years ago, not so very long ago, I heard an eloquent disquisition by a clergyman of Chicago on the mouth; he spent an hour in eulogizing the mouth to a class of dental students, and let me tell you that we are educating more dentists in Chicago than in any place in this country, and that is quite an achievement, which you would the more appreciate if you had only heard this learned gentleman's disquisition on the sweetness of the mouth as produced by dentists. I am not going to talk about the pharmacy men; there is one here, I saw him over in the corner (I got over into the corner too in order that I might escape) and we are doing well in training pharmacists, and you can see without my further enlarging on the subject that, while we have

not got a fully developed and equipped school of technology we have made a beginning at the Armour Institute and the Lewis Institute.

PROF. M. U. RICKER, UNIVERSITY OF ILLINOIS.

Mr. President and Gentlemen:—I have been exceedingly interested in the discussion. It concerns a question that all instructors have been obliged to consider, and very seriously, too. In my own experience, I have noticed that students with some previous knowledge of the subject that they desire to study, always acquire knowledge more rapidly, make a better use of it, know better just what they wish to accomplish, waste less time, and other things being equal, succeed best afterwards. For these reasons, I think Mr. Randolph's suggestion is undoubtedly a good one. A young man intending to be a civil engineer, who has thoroughly mastered the principles of mathematics, has certainly overcome one of the greatest difficulties in the study of the profession. After having served on such engineering work as he can perform, he will understand what engineering means. The incompetent young men, who really cause the greatest difficulties with which we have to deal, would be killed off by that process, or would go into some other and easier line of work. In other words, we should have the survival of the fittest, and we should get rid of the round men that take up a great deal of our time in trying to fit them into square or triangular holes. We never do succeed in this, and I think that this perhaps accounts for the fact that some engineers afterwards study law, dentistry, or something else, leaving the profession for which they are not fitted. This would eliminate that class.

Formerly in Germany, and I believe the custom is still retained there, it was the rule that an engineer should spend two years at an engineering school or technical high school, as it is called, then going out for two years' practice in the same line of work. He then returns and takes two more years of study, completing a six years' course in all. There is no doubt that such men are much better prepared at the end of four years' study and two years' practice than they would be after the course of study alone. They know something about the profession practically.

Another suggestion was made by Director Ricketts, I believe, with which I can hardly agree. The conditions were indeed somewhat different in the Rensselaer Polytechnic Institute. That is the earliest, oldest, most famous and undoubtedly the most successful institution of the kind in this country, possibly in the world. Its work was commenced under very different circumstances, since there were no specialists at that time. An engineer was required to be a good all round man, but since a vastly wider field of knowledge has been developed, he must now specialize. A large part of that special knowledge must be acquired by direct experiment and by the use of costly apparatus that cannot be supplied by his

personal resources, but only by a well endowed and equipped institution.

It therefore appears to me plain that this higher and advanced education can be imparted more thoroughly and rapidly at a technical institution than by private study after graduation. It certainly costs the student less, because he cannot make costly experiments in constructing hydraulic works, railways or bridges at the cost of the public, and which may be failures. It further appears that if there be a necessity for post-graduate education for literary graduates, there is much greater necessity for post-graduate instruction for the graduates of engineering colleges and schools. No institution in this country devotes itself to post-graduate work yet, in the way that Johns Hopkins and Clark universities do to advanced work in science and literature.

I would therefore suggest the possibility that the Rensselaer Polytechnic Institute might take up this advanced work, making it a post-graduate school alone, even if it were at first confined to a single branch of engineering.

In visiting the Columbian Fair, one of the points most interesting to me was to see the work done by graduates and professors of the leading and oldest educational institutions. The case of books written by members of the faculty and by graduates exhibited by Princeton University, and a similar exhibit by Harvard University, were both very interesting, but no educational exhibit impressed me so much as the magnificent collection of the work of the graduates of the Rensselaer Polytechnic Institute. The railway maps, bridges and works of all kinds were evidences of magnificent training. It therefore occurred to me to make the suggestion that post-graduate and specialized study can be best carried on by a school, and that no other institution has the prestige and might have the necessary equipment for this work, equal to the Rensselaer Institute.

Gentlemen, I thank you for the courtesy extended to me in behalf of myself, my colleagues, and the institution which we represent this evening.

PROF. THOS. C. RONEY, DEAN ARMOUR INSTITUTE.

Mr. President and Gentlemen:—I have been sitting here at ease, in the confidence that I was not to be called upon to speak, for the name of Dr. Gunsaulus, as I understood, is down upon the list of speakers. Why he should have slipped out at this juncture I do not know.

Prof. Roney: I confess I feel a little like the boy in the story—it may be a familiar story to some of you—who was a subject for discipline; in the absence of his father, his mother undertook to administer it. The boy made his retreat under the house and nothing could prevail upon him to come out. The father came home at night and hearing the account of his son's disobedience undertook to recover the lad; so getting down upon hands and

knees, he crawled toward the furtherest corner. As he came nearer and nearer to the boy's retreat, a little voice piped out: "Papa, is she after you, too?" (Laughter.)

Now, with all the characteristic modesty of a Chicago man who never fails to exhibit his modesty when opportunity offers, I have been turning over some comparisons in my mind, not exactly those suggested by President Rogers, but nevertheless of a very interesting nature. As I recall, this is the 73d anniversary of the founding of the Rensselaer Polytechnic Institute.

Prof. Roney: But one comparison is this, that we are only 70 years your juniors. Not the gentlemen are here compared, but the institutions. The first class of the Rensselaer Institute was, as I recall, graduated in 1826; our first class of graduates has not yet been born. However, we expect the christening to take place next June, and this is the time to extend to you an invitation to be present. I hope the wise men from the East and the wise men from the West will be with us. Your graduates are scattered over this country, and over the globe. If you will wait seventy years you may count ours, perhaps, in as many places.

But really, all I can say, called upon in this way, is simply to give the tribute of our admiration as a young Institute of Technology to the oldest one in this country, and to hope that seventy years may make us fully worthy to stand upon an equality with it.

PROF. G. N. CARMAN, DIRECTOR LEWIS INSTITUTE.

As the representative of Lewis Institute, it gives me pleasure to join with this body of engineers in expressing our appreciation of the Institute that is being honored here tonight, the oldest in the country.

The Lewis Institute can hardly claim as yet the honor of being called a School of Technology, in fact, there is some doubt as to the wisdom of carrying the work far enough to complete the training of engineers. As we have so recently started, I may say a word or two as to what has been accomplished.

It was in 1877 that Mr. Allen C. Lewis left a will at the time of his death indicating that his estate which was then about $400,000, be left to found an institution of learning here in Chicago. During the time that has elapsed, the estate has doubled and doubled again, amounting now to about $1,600,000. Ex-Mayor Roche, who is President of the Board of Trustees, undertook the work of planning the organization of a school. The building was commenced a year ago last May, and was completed last fall. It cost about $250,000. The doors of the Institute were opened September 21, 1896.

We have determined to make Lewis Institute a secondary school, an all-round school, the thought being to give that fundamental training that would make at least a good basis for the training of engineers, but not to limit it to purely technical or

manual training work. It is our desire to furnish a good, general education, to educate as far as possible those who have it in them to become engineers and to carry them far enough along the road to enable them to select among the institutions of this country the one best suited to their needs. We trust that the provision made is such as to accomplish this result.

We have now about four hundred students in the day classes and about two hundred at night. We are giving attention at night to those who are engaged in work during the day.

I appreciate the advantage of being present to listen to the discussion on training engineers. I thank you for it.

PROF. H. P. JUDSON, UNIVERSITY OF CHICAGO.

President Rogers tells us about the number of ministers we are training here in Chicago, and the number of doctors, and the like. Now I notice that our engineers, under the leadership of the accomplished gentleman present, are making that great drainage ditch and by and by I suppose that it will be finished. I speak with all deference to the chief engineer. But when it is finished I suppose that it will carry away our sewage and then the city will be more healthy and we shall need fewer doctors. Then the people will be more healthy and consequently more moral and fewer ministers will be needed. And so, frankly, Mr. President, my honest opinion is that perhape we need more engineers and fewer parsons and doctors—with all respect to both of those honored professions.

I regret very much that the President of our own university, Doctor Harper, is not able to be here. He was honored with an invitation, but he was obliged to be elsewhere. He is not an engineer, I believe, but he is an expert in the way of engineering money from the pockets where it is not needed into the coffers of the university, where it is needed. I have not a share in that sort of engineering except that from my position as a member of the faculty it is my duty to expend as much of it as possible, which I assure you I do.

It is a great pleasure to extend a greeting to the faculty and alumni of the Rensselaer Polytechnic Institute. It was my privilege at one time to be a citizen of Troy—a city to which I have always been most warmly attached—and I came to know something of that school. It is a school not richly endowed with millions of dollars, it is a school richly endowed with men—not with money, but with brains. I have known something of those men, I have known something of their high qualities of scholarship, their high qualities professionally as engineers, their high qualities as leaders of men, and I know that there are few schools in the country that can rank above the Rensselaer school in this respect. I am glad to extend to them a welcome on behalf of the city of Chicago, of which I am now a citizen and am proud of

being a citizen. It is not everybody who is proud of being a citizen of Chicago. There are some people who do not like Chicago. Some of our friends down East think it is a very bad city. Perhaps you will permit me to mention a true incident which may show the attitude of some Eastern people toward Chicago. Four or five years ago when the University of Chicago was in the process of getting into being, the members of the faculty were getting ready to come here, tearing up their old connections and coming to this new home. The night before a certain family started to come here the little daughter was saying her prayers at her mother's knee, and after having put in all her usual petitions she electrified the mother by adding, "And now God, good bye, we start for Chicago tomorrow." (Applause.)

Of course the child's remark impressed me. It showed the state of mind of a great many people about our fair city of Chicago. But after you have heard Dr. Rogers, you know it is not so, we have too many theologians. But we of the city of Chicago know what we owe to the engineers of the country, and we owe too much to the engineers who are graduates of that Institute not to do honor to it; they have done too much for the city of Chicago and the State of Illinois, not to have its name held in high esteem among us.

I am glad to welcome these gentlemen again as a representative of the University of Chicago. We have as yet no school of technology; we intend to have one; we intend to have one only when we can get enough money to found one on a large scale, on a scale commensurate with what we think to be the high importance and dignity of technological work, but we believe most heartily that technology is an essential part of the university. Of course, there was a day when a university consisted only of four faculties, philosophy, theology, law and medicine. That time has gone by, and we must add the faculty of technology to make a complete and rounded university. I do not know of anything more typical of our modern age than the engineering profession. It has done so much for the world. The world has moved on during the last century with tremendous rapidity, and a large part of our progress has consisted in getting things done, in material achievement, in conquering matter and conquering material forces and producing results that had been thought at one time to be absolutely impossible. But engineering science has told us that nothing is impossible to human genius, and so I think it typifies the spirit of our modern age more than almost any other profession. This is the age of material miracles, and you gentlemen are working those miracles every day. We know of course that there were in the middle ages, far back, great works of architecture, great castles and magnificent cathedrals, works which we admire and love. I have been told by an architect that there is a great difference between the mediaeval and modern architects in this, in those days they aimed to produce a certain result, and

they put their structures together so that they had to be strong enough to stand, but they had not the faintest idea as to what would be strong enough, and so they went on and made them as strong as they could possibly be made, and the result is that they are five times or twenty times as strong as the need would warrant. The architects had not the scientific knowledge requisite and nothing more, they did not know how to produce the result. A modern architect would construct a building as strong as the mediaeval, but with a great saving.

With regard to technical instruction, permit me to say simply one word. I find it hard in my own mind to compare a technical training with a liberal training. I find it hard to put them side by side, because I think one belongs on top of the other. If I had my way I should super-add the technical training to a liberal culture. I think this profession is so great a profession, that its needs are growing so elaborate with the advance of the intellect of the age that this is what is now needed. Of course, things must be managed reasonably and wisely, but I think the proper relation would be just as broad and deep a structure of liberal education as possible, and then upon that a thorough training in technical lines.

I agree most heartily with Mr. Randolph in his idea. I would give the boy not merely mathematical training, but as much training as I could; then throw that boy on the world and make him find out that things are hard and tough, that he has to knock his way through by sheer muscle and energy; then send him off to school, and he will realize that books are made of real things and real things are brought out in books. That will tend to make the profession of civil engineer a profession on as high a plane as law and medicine and theology should be—one of the learned professions—and put it on as high a basis as money and genius can provide.

Mr. President and gentlemen, I thank you most cordially for your kindness.

IRA O. BAKER, PROFESSOR OF CIVIL ENGINEERING, UNIVERSITY OF ILLINOIS.

Mr. President, I will try to speak "about a minute." I take great pleasure in rising to congratulate the institution which we are met here to honor. We all respect and cherish its long history. I know personally some of the men, and I was exceedingly glad to hear a previous speaker, not an engineer, bear testimony to the earnest, laborious, scientific work that its professors are doing. I know a little about it from hearsay, a little from personal knowledge, and I congratulate the engineering profession that there is such a school, and that it has such men in charge of it. I congratulate the engineering profession also that private benevolence and the state are willing to spend vast sums of money for the education of engineers.

I want to take exception to the last gentleman. He says he hopes that the engineering profession can come up to as high a plane as the professions of law and medicine and theology. I believe that the engineering profession has already passed those professions, and I do not say this with a desire to glorify ourselves, but only to inspire engineers with a respect for their profession. Engineering is at least entitled to rank as a learned profession. There are no requirements for admission to law schools, not even a high school education; any one can enter a law school who can sit on a bench, and he will be graduated after listening to lectures for a few months. There are no examinations for admission to most, in fact nearly all, medical schools; a man can go from the plow to most medical schools and become, after two short terms of study, a member of the medical profession. There are no educational qualifications for admission to theological schools. With engineering schools it is different. The conditions for admission and the courses of study are almost uniform. They require for admission a high school course of at least three years, and for graduation demand four years, of nine months each, of most severe application, and many of them re quire in addition considerable work during vacation. It is rea sonably certain that an engineering graduate has had a high schoo course and what we may call two years of general collegiate education and two years of professional training. Roughly, the time spent by the engineer in getting his professional training i equal to that given by the members of the "three learned profes sions," while the engineer spends more time in getting his preliminary education.

Of course, not all engineers are college graduates, but neither are all doctors or lawyers. Probably honors are about even in this particular. Time will not permit a further discussion of this subject, but engineering is truly a learned profession.

Fifteen to twenty years ago it was a common thing to hear practicing engineers refer with scant respect, as we professors thought, to the young engineering graduate. This was the result of a misapprehension which has passed away, for now when engineers want assistants they almost universally ask for technical graduates. Of course, the recent graduate is not an experienced nor a competent engineer; but it is reasonably certain that he is well grounded in fundamental principles, and is so equipped as to rapidly acquire valuable personal engineering experience. If you experienced practitioners will look upon the recent engineering graduate as a man just entering upon a profession that is already high and that is rapidly raising its standard, you will be more charitable in your judgment of the work we professors send out. We can not make men who are ripe with experience; we can only put them upon the ladder and send them up to you. We hope that after twenty years they can climb a little higher than you. They ought to, they have had greater advantages, they

started from your shoulders. And right here I desire to give the most heart-felt thanks to the members of the engineering profession for the help the engineering professors are continually receiving from practicing engineers. I am very thankful that I have had the help, the encouragement, of my fellow members of the Western Society of Engineers. May all labor together in still further advancing our honorable profession, and I hope that the institution with which I am connected, when it comes to its seventy-third anniversary, may have a reputation as honorable as the Rensselaer Polytechnic Institute.

REV. THADDEUS A. SNIVELY, CHICAGO.

Gentlemen, I am asked to speak at a very late hour. I feel a little hesitancy, too, after the suggestion made that there are going to be too many theologues, that perhaps it would be just as well for me to say something as to the energetic measures which the scientific men of Chicago at present are taking in order that the number of theologians may be lessened. I have heard a story of a young man who was new in the work of the ministry. He said to his Rector, whom he was helping, that he liked to visit the poor, but that he ran out of conversation; he talked about the weather and talked about the children and then his subjects gave out. The older man said, "Well, ask for a glass of water and that will give you a little talk." He came up next day and said, "I have made eight visits and drank eight glasses of water; what can I do next?" Think of it, eight glasses of Chicago water.

Gentlemen, just at the close of this discussion, representing what I believe is the highest profession, bringing something into life that is not discovered by your studies and therefore believing that I represent something that is of vast importance, as a clergyman, I want to bear tribute, first to the tremendous dangers that technical education has brought into human society, and secondly to the great things that it has done to relieve human society. You men of the Western Society of Engineers represent the mechanical work, the mechanical genius, the power of inventions in the world. I am not simply thinking of railroads, I am thinking of everything that concerns mechanics, because a graduate of this institute and I think a member of this society is the head of a great ship-building institution. You cover everything by your work and by your studies. You have multiplied the results of human labor to such a degree that the individual today is of comparatively little value. You take your great machines found in motion today and you make those machines do the work under the control of a few men that used to be done by thousands of men. And whatever you have done here, you have done all over the world. Here and elsewhere you have complicated the social condition to such a degree that the problem is becoming more and more complicated. While the individual laborer is facing an

increasing competition from mechanical inventions in gaining his bread by the sweat of his brow, you have also made it possible for colossal fortunes to come into the possession of single individuals, men of genius and men that must be protected. These are the conditions which are facing the social student today, and you have made them.

On the other hand then, you gentlemen are the means of making possible the relief of distress. It matters not if it is in far-off India, or in Russia or Turkey, you make help possible. When we come to study the situation, we find, I think, that the danger in India today as in the past is that there are not enough railroads there in order that the product of the earth in one portion of the vast Empire may contribute to the need and distress and hunger of other portions of the great Empire. You have made the brotherhood of the race practically possible. Through your inventions and work, we find the nations are coming together in a sense of brotherhood and oneness which forms a sacred tie.

But you are doing more than that. The military engineers, what are they doing today? They are making war so terribly dangerous and the engines of war so tremendous that war is becoming less and less probable. The nations of Europe are facing each other and would go at once at the execution of selfish war except that they fear the results of your own inventive genius as stored up in the engines of war of their adversaries. So you have made war less likely, and I wish I could be the means tonight of simply putting into the minds of some of you the great necessity of this country of victories of peace—the tremendous importance of having a mutual agreement with that other English speaking nation to come together upon this treaty of arbitration. (Applause.) We want you to do all that you can for the victories of peace. The competition of commerce and of manufacturing can not be helped and the results of them we must face, but the dangers of war, the slaughter of human life for the mere sake of protecting one country against another on some fancied ground of slight or misunderstanding, my dear friends, we ought to do all that we can to keep that down.

I thank you tonight for your kindness in calling on me. It is a great pleasure to me to meet these gentlemen of the Rensselaer Polytechnic Institute. I want to bear my testimony to the work of the faculty of the Rensselaer Institute. I lived 11 years in Troy; I had the pleasure of preaching the Baccalaureate sermon thrice during that time; I loved the men of the faculty; I was interested in that institution more than I have been interested in any institution save the one from which I myself am a graduate. I would like very much to have been a graduate of the Institute at Troy. I do not know whether the Civil engineering would cover the work of the pulpit or not, but I want to tell you that the minister of a modern congregation wants to be a civil engineer, he must be a military engineer at times, and he must be somewhat of a diplomat. The men at the Institute of Troy have

a pride in their work, and well they might have when one contemplates the splendid roll of its graduates and the work they have done. I thank you for your kindness.

CAPT. ROBT. W. HUNT, MEM. W. S. E.

Mr. Chairman and Gentlemen: I would be dumb indeed if I should refuse to respond to this kind invitation to say a few words to you. They shall be few, because they come very much more from my heart than from my intellect, I assure you, because, according to the proposition with which we are all familiar, it is the larger which predominates the smaller, and I trust that when I come to be weighed up in the balance, though there may be a want of one, it will be found that there was enough of the other to make me at least meet Brother Snively on that Golden Shore.

I feel that I have but little business to talk to you on technical education, because I only know it from observation; it was not my good fortune to have it, and how many, many times during my somewhat busy life I have missed and felt the loss of the advantages and the strength which it would have given me. I think I have shown sense by getting around me in these later years, and in fact during my years of administration of affairs, those who did possess it and have endeavored to see that while serving me they have better served themselves.

But, gentlemen, times have changed so greatly during my life that, looking back, I can appreciate that if I were to begin today where I started those many years ago, how much less able I would be to face the world We have gone through periods of most wonderful development, developments on the lines which had hitherto been thought incomprehensible and absolutely unanticipated. We cannot today conceive that at least the immediate future will present such opportunities to human mind and human effort. In my own case it happened that my active life commenced just about the time that the discovery of Bessemer was launched upon the world. Mr. Bessemer, with all his great attainments, was ignorant; I say he was ignorant because the science of chemistry had not reached the point where it is today. As an illustration, let me tell you that he promulgated the rule that iron which contained over two hundredths of one per cent of phosphorus would not make Bessemer steel, when we now know that much of the very metal that he was using had one-tenth of one per cent of phosphorus. So that the development of that industry, that which has made possible the railroad progress, and through that the general material progress of the world, was fought out, even though the founders were in the dark in relation to some essential principles.

I had what education a boy left at 16 years of age to fight his battle of life could get. I had to take advantage of those opportunities which were presented to me, and it was my good

fortune to meet such a situation as just stated. But today I cannot conceive a young man being so fortunate, therefore he should be grounded by a good education, and if I could follow my idea of the way that he should be educated, it would be somewhat on these lines. And right here let me tell you, gentlemen, our young men are too anxious to get to work. The years are longer and there are more of them than they think. I believe they can well afford to spend a few of them at the commencement of their life in forming the groundwork on which to make the success which we hope they will enjoy in the great future before them. Therefore, I heartily echo and voice the sentiment to give a boy a good general education, classical if you have time and means; then make him do some work, and by that time you should be able to judge of the best lines for the development of his mind. We cannot all be engineers and the world does not want us all to be. The history of the Rensselaer Institute proves how few, how small a percentage of men are calculated to be. This is shown by a class from the entering to its graduation losing so many by the way. And as President Peck said, not because they were below the average, but because their minds were not adapted to the requirements of that particular kind of education.

Now, by the time that this young man has gained this general education and has actually worked some, he and his guardians or parents ought to know the lines on which he will stand the best chances of success. Then give him his further education. Based on the above experiences, it should be easily determined whether he is fitted to receive a technical one, or better fitted to be in the so-called classical lines.

It is here that I think our great school at Troy comes in. If he is to be an engineer, send him there. It will give him a foundation fitting him for any future engineering work. A mathematical foundation, a groundwork that will be of the greatest service to him. Then, after he has graduated from Troy, give him a post-graduate course in some school, such as Cornell, for instance, and by that time he may be 24 or 25 years of age, and he is young enough and he is old enough, and he is ripe. He is ready to go to his life's work. The idea that the very minute a man reaches 21 and can count as a factor in determining who is to be President of the United States, that he ought to be controlling things in this country beyond that vote is a mistake. The country is too old for it.

Gentlemen, I am not going to detain you longer. We who are of Chicago and were formerly of Troy have our hearts made glad by the opportunity to welcome the representatives of that Institute here. Our hearts have been made glad, and we of the Technical Club are glad to have this opportunity of welcoming you; and we of the Western Society of Engineers—you know how dear that society is to my heart—we are glad to have this opportunity to extend this welcome. I thank you.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

THE ELECTRICAL TRANSMISSION OF ENERGY.

(Synopsis of a Lecture at the Rensselaer Polytechnic Institute, by Charles E. Emery, Ph. D., February 10, 1897.)

MR. PRESIDENT AND GENTLEMEN—There is considerable embarrassment in treating a subject of this magnitude in a single lecture. In order to interest those who have not yet studied the matter it seems necessary at first to state briefly some elementary principles, and finally to traverse the whole ground, making a special feature of the relative cost of water power transmitted electrically, compared with the cost of steam power, and illustrating by various practical applications in different parts of the country.

Of the many sources of energy in nature we are only able to utilize practically every day that due to the energy of the sun, which lifts the aqueous vapor to the heights and thereby produces, in the present, our water powers, and which, in the past, promoted a dense vegetation, finally transformed, in the laboratory of nature to coal, which furnishes, in the present, the principal source from which heat engines of different kinds derive their energy. The steam engine is the form of heat engine found in use in all locations and in all branches of manufacture, and has therefore naturally become the standard of comparison. Where water power is available the chief cost is the first installation, after which the continuous charge is only for interest, repairs and attention, while, with the steam engine, the cost of the fuel is to be added to the other general items. It follows therefore that the original cost of, and therefore the interest charges on, a water plant can be made considerably larger than for a steam plant, and the former still show an advantage, but, if the water power is to be transmitted, the interest charges apply not only to the cost of the development of the water power, but to the cost of the means of transmission, and it becomes evident that it may be possible to so increase the interest charges that they will balance the cost of fuel, particularly where the latter is cheap. For these reasons it is found that it will not pay to develop water powers in every location, and we shall see as we proceed that the profits to be derived from the larger undertakings of this kind are not nearly as great as they would appear to be when one sees the enormous waste of energy at a large waterfall. The disadvantage attending the development of water power on small streams is evident upon brief consideration. Manufacturing establishments require steady power.

In all the smaller streams the flow of water varies with the season, and even in large rivers the minimum flow, which is all that can be depended upon for steady power, is generally a moderate proportion of the average flow throughout the year. Natural lakes or artificial reservoirs, properly regulated, tend to steady the flow and increase the amount of power uniformly available. The storage required to produce one horse-power for one hour with an available head of 10 feet would be represented by the capacity of a tank 20 feet square and 10 feet deep, and at a head of 140 feet like that at Niagara Falls the storage tank would still be required to be 10 feet square and about 3 feet deep, elevated 140 feet above the wheel. Fix the size of this tank in mind, in the corner of the room for instance, and consider that the same power would be produced through the instrumentality of a steam engine with 2 to 4 pounds of coal, which could readily be carried in a paper bag.

These illustrations show that water power can only be directly utilized along the lines of natural channels calculated to convey it in sufficient quantities for the purpose. The comparatively large amount of energy stored in coal has made that the best source of power at distances from waterfalls out of the range of ordinary means of transmission. Mechanical means of transmission operate within very limited distances. We have, however, been enabled within late years to increase these distances very materially by the use of electrical transmission.

All the principal details of electrical apparatus were developed with electric current derived from the chemical reactions in an ordinary galvanic battery. The source of energy was therefore so limited that the commercial availability of electric apparatus for electric lighting and power purposes commenced with the evolution of the modern dynamo, based on the apparatus of Pacinotti, first announced in 1864, and soon after that date, power could be transmuted into electrical energy in any quantities desired.

Electrical transmission has been made commercially practicable within the last seven years by the perfection of methods and apparatus and the great reductions in the cost of the latter. The advance has taken place rapidly, but has nevertheless been thorough, so that there is no probability that there will be any material change in commercial conditions in the future. Electric machinery is now constructed on a business basis and sold for about the same price per pound of finished material as other machinery, and patents have very much less influence on the result than in former times. The later apparatus has, moreover, as nearly reached the theoretical limit of efficiency as can be desired.

One important element of progress has been in the development of apparatus which will permit the use of higher electrical pressures or electro-motive forces than formerly. The non-technical may consider the phenomena of electricity as if it were, what it probably is not, a fluid possessing volume and delivered at a

certain pressure, the volume being known as "current" and measured in "amperes," and the pressure known as "electro-motive force" (e. m. f.) and measured in "volts." The simile is helpful, though it connot be carried to an extreme. Formulæ based on Ohm's law show that a given amount of energy will be transmitted over electric conductors of a given size to distances proportioned to the square of the electric pressure or electro-motive force. That is, by doubling the e. m. f. the distance may be increased four times. For long-distance transmission, the copper in the line is one of the most important elements in the cost, and the above considerations show that to secure economy in the copper, the voltage must be as high as practicable. Ordinarily, limitations as to electric pressure are imposed by the use of particular apparatus and to secure safety. Buildings are customarily operated with incandescent lamps at a pressure of 100 to 127 volts; but on the Edison three-wire system, part of the lamps are supplied at plus 127 volts and part at minus 127, so that the electrical difference in pressure between the outside wires is a little over 250 volts, which is utilized for operating the larger motors. Electric railroads are usually operated at from 500 to 600 volts, which is about the limiting pressure which can be endured by human beings, though sufficient to kill a horse. Arc lamps are, however, operated in series, with a difference of potential at terminals of dynamo of 2,000 to 4,000 volts, so that such circuits are extremely dangerous.

For more important electrical transmissions alternating current is employed, or that in which the current surges back and forth, urged by alternating electro-motive forces which reverse sign 25 to 133 times per second, giving, as it is called, that "frequency" or that number of "complete periods" or "cycles" per second, and double that number of "alternations" in the same time. For circuits chiefly used for power purposes, frequencies as low as 25 to 30 are desirable, and give increased efficiency, but the higher frequencies are used for electric lighting and in some cases an intermediate number of cycles employed fairly adapted for either light or power. Motors are designed for use at all frequencies, but usually operate with a little lower efficiency on circuits of higher periodicity.

Alternating current apparatus has special advantages for the development of high voltages, for the reason, first, that commutation is not necessary, and, second, that alternating current with any pressure or voltage can be readily "transformed" to any other voltage without the use of moving mechanism.

While no exact definition of electricity or magnetism is possible, there is a definite mathematical relation between the two, as it is positively known that when an electric conductor is subjected to the influence of a variable magnetic field an electro-motive force is generated in such conductor, proportioned to the rate of change in magnetism. If, therefore, a conductor carrying alter-

nating current be wound on an iron core, the continual change in the rate of magnetism, due to the reversals in the direction of the current, tends to cause electro-motive forces called "counter-electro-motive forces," which are antagonistic to, and tend to hold back the original or primary current and at the same time tend to produce current in another conductor wound parallel to the first, or on the same core. Calling the circuit carrying the primary current the "primary," and the parellel circuit the "secondary," the voltage in the secondary circuit may be made any proportion of that in the primary by simply varying the number of turns, but the work done in each will be the same, less ordinary losses. For instance, 10 amperes at 100 volts in the primary will in a secondary containing $\frac{1}{10}$ the number of turns give 100 amperes at 10 volts. This is called "step-down" transformation, because the pressure is reduced. If, however, the primary contains a fewer number of turns, the pressure in the secondary is increased, which is called "step-up" transformation. It will be observed that this operation is performed without moving parts, the variations in the strength of the current producing results akin to those resulting from the motion of the conductors of an ordinary armature across a magnetic field.

Ordinarily the primary and secondary coils are laid close together and the magnetic circuit is disposed in rectangular shape so the large transformers take the shape of a box.

It will be seen that an alternating current may be generated at a comparatively low voltage, or one which is safe to human life, and causes no difficulty with the insulation of the moving parts, and that the energy thus developed may by step-up transformation be transmitted with lower current and higher voltage to a distance where by means of step-down transformers a large current and low voltage may be obtained for lighting and power purposes.

Alternating current motors are of several kinds, such as synchronous motors, very much like, and running in step with, the generators, that is, so as to pass the same number of poles in the same time. These motors are preferred for large installations. With moderate powers, electric transmission is preferably made with what are called polyphase currents, or several currents in which the phases or maximum e. m. f.'s are not coincident. In polyphase motors of the induction type, the armatures carry conductors short-circuited on themselves. The action of the alternating currents on the pole pieces is to induce current in the conductors of the armature on the transformer principle, which currents are attracted by the field produced, and motion results.

It is possible to transmit power electrically by alternating current by passing the former in at certain points of the armature of an electric generator and taking the same out as direct current, by commutators and brushes the same as an ordinary direct-current machine. Such an apparatus is called a rotary converter.

COST OF STEAM-POWER.

1	2	3	4	5	6	7	8	9	10	11	12	13
			Cost per Net Horse-Power.									
	Kind of Engine	Net Horse Power	Per Hour for Coal at $3.00 per ton*	Per Hour for Labor	Per Hour for Supplies and Repairs	Per Hour for Sinking Fund, Taxes and Insurance; 5% of total cost added to.		Per Hour for Coal, Labor and Supplies	Total per Hour		Total per Year of 3080 Hours	
						5% Interest and Dividends	10% Int'r'st and Dividends		For 5% Interest	For 10% Interest	For 5% Interest	For 10% Interest
			Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Dolls.	Dolls.
A	Ordinary Non-Condensing	10	.9705	1.00	.28	.1948	.2921	2.25	2.45	2.54	$75.46	$78.31
B	Automatic Cut-off Non-Condensing	75	.5556	.37	.19	.2110	.3165	1.11	1.33	1.43	40.96	44.04
C	Automatic Cut-off Condensing	150	.4239	.25	.14	.1948	.2921	.814	1.01	1.11	31.11	34.19
D	Compound Condensing	250	.3465	.17	.09	.2078	.3117	.607	.815	.919	25.18	28.40
E	Triple Compound Condensing	500	.2697	.11	.08	.2338	.3507	.460	.694	.811	21.38	25.06

*As stated in the text, the coal per hour has been calculated on a conservative basis designed to represent average practice rather than the results possible with apparatus in perfect condition. The basis is 42 pounds of feed water per H. P. per hour for line A, 28 lbs. for line B, 22 lbs. for line C, 18 lbs. for line D, and 14 lbs. for line E, and evaporations per pound of coal of 7½ lbs. for line A, 8.25 lbs. for line B, and 8.5 lbs. for the remaining lines. With engines of the kind stated, proportioned for the work and in good condition, the water consumption should be 2 pounds less for each engine, and an evaporation of 9 pounds of water or better per pound of coal could frequently be obtained. As the costs are generally stated for the indicated horse-power, it should be noted that a friction of 10 per cent has been assumed to cover losses not only in the engine, but due to transmission to a jack shaft. For engines running 24 hours per day, the allowance of 10 per cent of the fuel for starting and stopping fires should be decreased. Engines generally keep up their economy for long periods, but the amount of coal is frequently increased by carelessness in connection with the selection of the fuel, the firing, care of boilers, &c.; so, even if the engines require 2 pounds less water than assumed, the coal required generally costs fully as much as stated.

The accompanying table shows the cost of steam power under conditions differing as to type of engine and amount of power required. There are so many conditions affecting the problem that the subject cannot be fully presented in so small a compass, but the table gives a general idea of the details of the cost of steam power, and shows the approximate costs under conditions to be stated. The calculations are based upon coal at $3.00 per ton which will apply to a large number of locations. The table shows that the cost of a H. P. for a working year of 308 days (which excludes Sundays and holidays) and for ten hours per day, is as shown in column 12 from $75.46 down to $21.38. The latter result can, however, be obtained under experimental conditions. For every hour in the year these prices would become $213.00 and $61.00 respectively. The cost of a H. P. for an hour given for the larger engine is 0.69 of a cent. In ordinary practice with variable power such cost is about one cent per H. P. per hour, or one H. P. hour as it is called, or $30.80 per year per H. P. continued for ten hours per day and 308 working days in the year. For small engines this cost will be increased to about 2½ cents per H. P. hour or $77.00 per H. P. per year. For very small engines the prices will be still higher.

The cost of a water power on streams reasonably free from ice and of floating obstructions is principally due to the interest on the capital invested. Very many water powers can be developed very cheaply and when done substantially, the operating expenses are comparatively small, consequently there should be very many locations where water power, if reliable, should prove considerably the more economical. The drawback to the development of valuable water power as heretofore has been the lack of industries at the site of the falls to utilize the power. As the country grows, the demand for power increases, and moreover, the development of electric transmission enables such power to be utilized at a distance so that the conditions are now very much changed. The cost of the electric transmission adds to the cost of the plant and increases the cost for interest, but still there are many locations where the water power may be developed at such low rates that the additional cost of the electrical apparatus is fully warranted. At a number of points in different parts of the country, water power has been developed in considerable quantities at from $8.00 to $12.00 per H. P. per year, the cost being made up by allowing 5 per cent for interest, 2½ per cent for sinking fund, 1½ per cent for repairs, 1 per cent for insurance, or a total of 10 per cent on the cost, with 75 cents per H. P. for attendance, oil, etc. On the contrary, the water power on the Merrimac, calculated on the same basis, apparently cost about $30.00 per H. P., or practically the same as steam power, but this cost includes certain rentals which are in the main returned to the owners through the water power company, which is itself owned by the mills, for which reason, and the fact that the real estate investments have

been very remunerative, the annual cost of the power is considerably less than the apparent cost. It is, however, a fact that cotton mills can be operated profitably by steam power without water power, as shown by the considerable number of steam mills at Fall River and New Bedford, Mass., and elsewhere.

This preliminary discussion of the facts available will be of assistance in an examination of the outlook for companies incorporated to develop water power and distribute the same electrically. The desirability of employing electricity for transmission to a distance is evident, but the decision of a number of eminent experts, in relation to the enormous development of power, proposed by the Cataract Construction Company at Niagara Falls, was that it was cheaper to distribute power locally by means of electricity than by the use of ordinary mechanical methods, and that the transmission of power to a distance could be part of the same system. In carrying out these views, units of 5,000 H. P. were adopted, each consisting of an electric generator and a direct connected turbine of sufficient size to operate the same. The full cost of the work at Niagara Falls has not been published, but estimating from general information it is thought that the hydraulic development for 80,000 to 100,000 H. P., to include head and tail races, head gates, wheel-pits, wheels and mechanical means of transmission from the wheels to the dynamos, together with necessary buildings, water rights, promotion expenses and the land needed for the work, independent of investment in extra property, should not cost more than \$30.00 per gross H. P., or \$42.75 per net H. P. delivered. It is probable, however, that to secure capital for such an enterprise the original cost, represented by the securities issued, would be considerably greater than stated. Moreover, it would not be practicable to develop at once the whole of such an enormous power, though the principal portion of the expense would necessarily be incurred at the outset. These considerations might raise the cost of plant to \$80.00 per net H. P. delivered.

At present prices it is considered that the cost of local electrical transmission will not exceed \$40.00 per net H. P. The total cost of plant would then on this basis be \$120.00 per H. P., and allowing interest and fixed expenses as before, and \$1.50 per H. P. for running expenses, makes the yearly cost \$13.50 per H. P. With the cost price as low as this, the power company should afford to sell at a profit power for \$15.00 to \$18.00 per year per net maximum H. P., and the advantages to consumers would be very apparent compared with 24 hour steam power every hour in the year for \$61.00 to \$88.00 per H. P., or even 10 hour working day steam power at \$30.80, or for coal at \$1.50 per ton, say, \$25.00 per H. P. per year.

Long distance transmission in large units differs only from local transmission in requiring the employment of longer electrical lines and the use of step-up and step-down transformers previously re-

ferred to. The double set of transformers in large units will cost only about $11.00 per H. P., and for a transmission of 20 miles at 10,000 volts the copper in the line will cost about $21.50 per H. P. The total cost of the hydraulic and electrical development should not exceed $150.00 per H. P. delivered, so, calling the cost of attendance $2.50 per H. P. and deducing the interest and fixed charges as before, the yearly cost would be only $17.50 per H. P. Promotion expenses, the interest accumulating on bonds during construction, and other expenses incident to financing a large operation of this kind would probably increase the cost greatly, still it would appear that the transmitted power should be sold for $20.00 or at least $25.00 per net H. P. in large units along the high tension lines, which would still show an advantage over steam power developed with coal at $3.00 per ton, and at the worst stand on an equal footing with ten hour steam power developed in large units with coal at $1.50 per ton above stated.

Everything considered, it may be assumed that prices will be adjusted so as to make it advantageous for large consumers to use the power, and the high tension lines be run to their premises for that purpose. A large expense is necessary, however, to distribute such power to small consumers. Two methods of distribution are practicable, one to reach the power houses of companies already installed and utilize their lines, the other to transmit the power locally through lines at lower tensions, though much higher than have been employed until quite recently. If such distribution be attempted through companies already installed, as first assumed, their plants have already cost several times as much as we have estimated for the entire transmission plant, and interest and dividends must be paid on the whole capital invested, consequently a saving of $5.00, or even $10.00 per H. P., would not be such a proportion of the necessary total cost, including interest, as to make a great difference in the charges to small consumers.

The attempt to establish a new distribution in a city already containing local companies for the same purpose, would necessarily meet with opposition, and if forced through the cost of making the distribution in the most economical way, would be so serious that power in small quantities would still be so expensive that a very large use could not be predicted, in competition with 10 hours steam power where coal is less than $3.00 per ton.

It is improper to calculate that all the power available can be sold at the prices now charged by the electric lighting conpanies, or for from 4 to 6 cents per H. P. hour instead of one cent for large engines and 2½ cents for small ones previously mentioned. Such companies necessarily charge large prices, principally on account of the large amount of capital invested, and large operating expenses, independent of the cost of coal, and such prices are advantageous to small consumers from the fact that the power supplied is convenient, always available on demand and costs nothing during periods of disuse. It is true that the uses of

power are greatly extending in the larger cities even at these prices, but the applications are generally in very small units, and the whole output for this purpose is very limited compared to the total amount of power used in the city, the majority of consumers cannot be reached without reducing prices nearly as low in some cases, and in others lower than for what the same work can be done by the steam engine. In making the comparison, the use of the steam plant, and particularly of exhaust steam in winter for heating purposes, must be considered.

These remarks apply principally to 10 hour working day power or variable power for which the means is a moderate fraction of the maximum. For steady power during 24 hours, the regular local companies could afford to make large reductions, and a special power branch of an electric transmission company gives very satisfactory prices, for the reason that the number of hours' service does not increase the cost of water power, whereas the cost of steam power is practically proportioned to the number of hours it is used. Even, however, if the transmission company obtained prices approximately as high as are now charged by the electric light companies for very small powers, and made rates which appeared reasonable for 24-hour power, it would still be unable to give satisfactory prices to the large amount of 10-hour power which goes so far in making up the aggregate, for the reason that it costs the transmission company practically as much for 10-hour power as for 24, and charges must be made on that basis. That is, the transmission company could not reduce its price in proportion to the number of hours used, or sufficiently to compete with steam power where coal is less than, say, \$3.00 per ton. The same would be true for variable power continued through 24 hours when the average power is much lower than the maximum.

If the average powers during each hour be summed for the entire year, the total horse-powers per hour, for that time, will, in most cases, be found not greater than if the maximum power were continued for 10 hours per day during the working days of the year, or for 35.2 per cent of the total time. This 35.2 per cent is called the "power factor," and is generally expressed as the relation between the average power and the maximum power, which would give the same result. It follows that if for each maximum horse-power, only 3,080 H. P. hours were developed in the year, or the same as for a 10-hour day, the cost at one cent per H. P. hour would be only \$30.80 per year, and therefore the charge for water power, although available every hour in the year, must be sufficiently less than \$30.80 per year to warrant the change, although the same user of steam power could afford to pay \$87.60 per H. P. per year if he used the power every hour in the year.

These considerations are well illustrated by contract recently made by the Cataract Construction Company with the Buffalo Street Railway Company. The railway company is to be furnished 1,000 H. P. day and night, for \$40.00 per H. P. per year, and apparently

pays $45.00 per H. P. for apparatus, 10 per cent of which on basis stated in text, makes the total cost $44.50 per H. P. per year. If 1,000 H. P. of steam were actually used every hour in the year, it would cost, at one cent per H. P. hour, as stated in text, $87.60 per H. P. per year; so the railroad company has made a good bargain, even if 1,000 H. P. are not used all the time. Additional power is to be furnshed for $36.00 per H. P., equivalent to $40.50 with fixed charges added as above. The load of the railroad, less 1,000 H. P., must show a very low power factor; but if it be as high as 35.2 per cent, this represents, as explained in text, a cost for steam power of only $30.80 per year per maximum H. P., showing that 24-hour power can be furnished advantageously by transmitted power, but that questions arise for 10-hour power or variable power of an equivalent number of H. P. hours.

The possibility of electric transmission of power was foreseen by very many parties in different parts of the world, and some comparatively unimportant applications were made from time to time, but an historical work would be necessary to give the same proper credit. The growth of the business as a commercial industry practically began with the Electrical Exposition at Frankfort in 1891, where electric energy was transmitted from a waterfall at Lauffen 108 miles away. The cost of this particular plant was so great that the power developed at Frankfort really cost some four to five times as much as it could have been developed for with steam machinery on the spot, but the installation settled a large number of doubtful questions and warranted the application of such transmissions in evidently favorable locations, thereby bringing about a reduction in the cost of apparatus and opening a wide field for such enterprises.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—3D OF MARCH, 1897.

A regular meeting (361st) of the society was held in the rooms of the Technical Club, 228-30 South Clark street, at 8 o'clock, Wednesday evening, 3d of March, 1897.

President Thos. T. Johnston in the chair, Nelson L. Litten, secretary, with. 77 members and guests present.

The minutes of the previous meeting were approved as printed.

President Johnston referred to the courtesy of Congressman Hon. J. Frank Aldrich in securing certain public documents for the society's library, and a vote of thanks was given Mr. Aldrich.

Mr. Reynolds called the attention of members to their privilege of aiding in the increase of subscriptions to the Journal.

Mr. E. E. Johnson then introduced the subject of the evening, "Deep Well Pumping," by reading abstracts from his paper and with stereopticon illustrations of machinery and diagrams relating to his new apparatus in pumping water. Mr. Ball read a discussion prepared by Mr. A. F. Nagle which was listened to with interest. Mr. Jas. F. Lewis followed with verbal and written discussion having reference to the advantages of air lift plants. Mr. D. W. Mead, of Rockford, Ill., made interesting citations of experiences and results in the efforts to supply his city with water. Mr. C. C. Stowell, city engineer of Rockford, Ill., furnished additional data regarding the matter at Rockford. Messrs Melcher and Windett made valuable statements in their discussions. During the discussion Mr. E. E. Johnson made replies and explanations to various questions.

In closing Mr. T. T. Johnston rounded up the matter by comments covering the various views and statements made by the several speakers. On the whole, the subject proved to be of great interest, aroused profitable discussion and produced a valuable array of data.

On motion the meeting adjourned.

MEETING—24TH OF MARCH, 1897.

The mid-month meeting (362nd) of the society was held in the Technical Club rooms, on Wednesday evening, 24th of March, 1897. President Thos. T. Johnston in the chair, Nelson L. Litten, secretary, with 34 members and guests present.

The minutes of the previous meeting were read and approved.

The secretary made report for the Board of Direction as follows: At a meeting Tuesday, 23rd March, 1897, the following gentlemen were declared elected.

As members: Frederic A. Delano, Daniel Royse, Wm. M. McCartney, Jas. F. Clarkson, Chas. P. Chase, Geo. H. Cook, M. C. Bullock, Wm. S. Love.

As junior: Wilson P. Hunt; as associate, Jerome A. Ellis.

The following applications for membership were received: Henry E. Vanderlip, Henry W. Carter.

There being no further business and Mr. Clement F. Street being unavoidably absent, the secretary read Mr. Street's paper on Railway Ties in India. At its conclusion Mr. H. G. Hetzler, of the C. B. & Q. R. R., presented his views arrived at from experience and general practice, which were not favorable to metal ties in this country on the score of economy or necessity.

Mr. Geo. S. Morison presented numerous points of interest on the conditions of climate and soil in this and other countries which must be considered in deciding upon the economical and practical uses of materials in road con-

struction. Reference was made by Mr. E. P. Humphrey to the successful and satisfactory use of metal ties on the N. Y. Central at certain points. Mr. J. W. Beardsley suggested the feasibility of planting trees which would arrive at a usable age for ties in a reasonable period.

On motion the meeting adjourned.

REGULAR MEETING—7TH OF APRIL, 1897.

A regular meeting (363d) of the society was held Wednesday evening, 7th of April, 1897, at the Technical Club rooms, 230 South Clark street.

First Vice-President Alfred Noble in the chair; Nelson L. Litten, secretary, and 28 members and guests present.

The minutes of the last meeting were approved as printed.

There being no business before the meeting, Mr. R. D. Seymour was called and read his paper on "The Britts Landing Cable Hoist and Quarry," which was illustrated with stereopticon views.

Mr. E. R. Shnable followed with a paper on "Deflection of Wooden Stringers."

A discussion of this paper prepared by Mr. Emil Gerber, who was unavoidably absent, was read by the secretary.

Mr. W. H. Finley also presented a written discussion of the subject, and was followed by oral statements from several members.

Mr. L. K. Sherman read a series of comparisons of deflections made with Mr. Shnable's tables.

On motion the meeting adjourned.

NELSON L. LITTEN, Secretary.

Journal of the Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

VOL. II. JUNE, 1897. No. 3.

VII.

RAILWAY TIES IN INDIA.

By CLEMENT F. STREET, M. E.

Read March 24th, 1897.

As the forests of this country are becoming depleted in an increasing degree from year to year, and as the, at one time, seemingly inexhaustible supply of available timber becomes less, we hear more and more about the use of metal as a substitute for wood in all manner of construction. The railway tie comes in as an important subject for a full share of thoughtful discussion, and it seems to be generally admitted among engineers that at no very distant day it will be impossible to obtain sufficient wood for supplying the large quantity of ties which are consumed by our vast railway systems. As the price of the wood tie is gradually increasing, and the price of the steel tie gradually decreasing the relation between the two will at some time reach a point where it will be cheaper to use steel. Varying conditions will command consideration in each individual case, and no general rule will ever be applied to all roads. The problem will have to be solved for each road or for each division of each road, and the proper solution of this question will be one of the nicest problems ever presented to the engineers of this country. It will be a problem having many important phases. There will be the comparative cost of materials to begin with, and then the character of the soil in which the ties will lie, the ballast, and the all-important question of design, as well as many other points, each of which must be given careful consideration, as a little poor judgment on any one point may result in a wasteful expenditure of money.

Experience is the great teacher in all things, therefore it is my purpose in this paper to describe some of the designs now in use on the railways of British India, in which country metal ties have probably been and still are more extensively used than in any other on the globe, although wood ties are still used in large numbers throughout that country. In metal ties there are three distinct types known as the Cast Iron Pot Sleeper, the Denham-

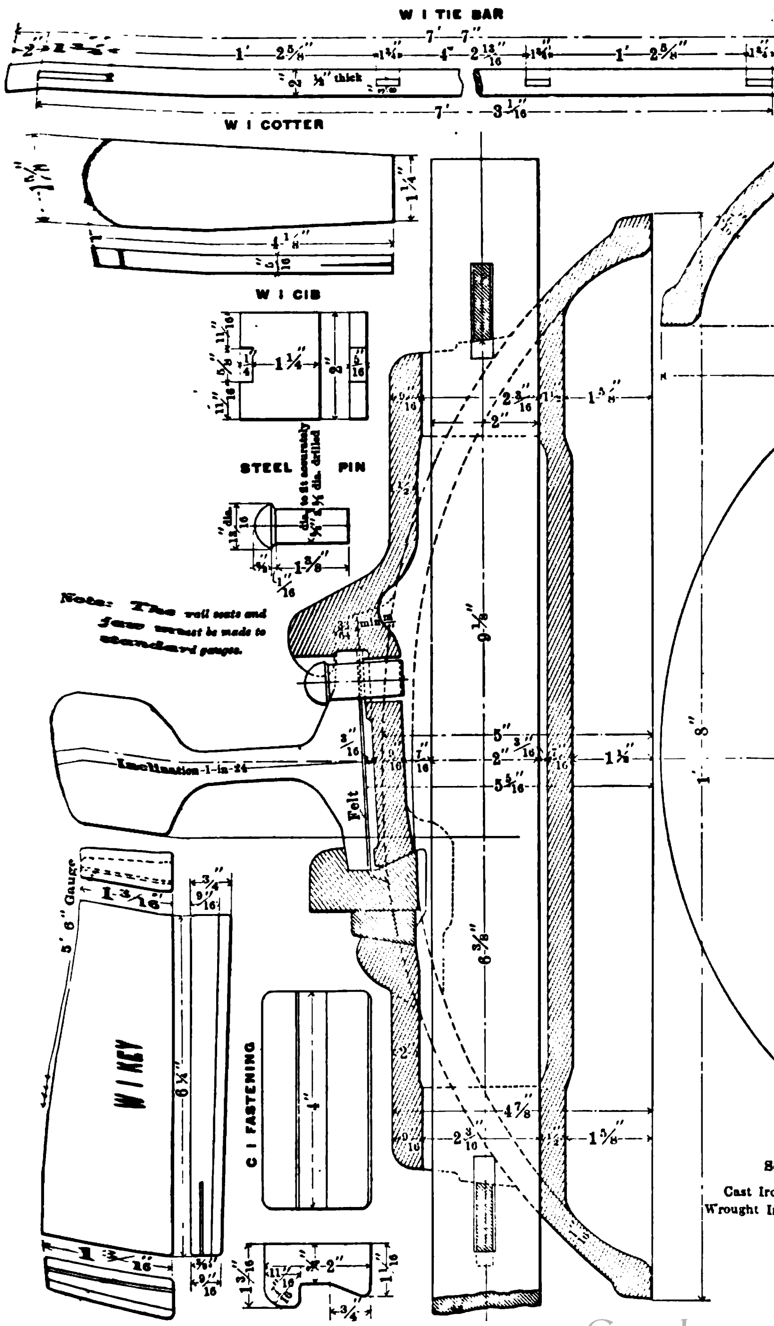
Olpherts Sleeper and the Peapod or pressed steel sleeper—the word sleeper being universally used instead of tie as is customary in this country. The accompanying illustrations give the form and important dimensions of each type.

In the Cast Iron Pot there is a difference in the weight and design adopted by different roads and the illustration, Fig. 119, shows that used by the India Midland Railway which is a system comprising 735 miles of track, having an equipment of 111 locomotives and 2,500 cars. It will be noted from this illustration that each sleeper consists of two inverted bowls or pots, one being located under each rail of the track and connected by a wrought iron bar or strap, each end of which is keyed to one sleeper. The outside of the rail, which is of the flat-footed type and weighs 80 lbs. per yard, is held in place by a lug cast on the pot and lies against a lip 17 inches long and one-half an inch high. The inside of the rail is held to the pot by a heavy cast iron clamp which is in turn held up to its work by a wrought iron key driven behind it. This fastening always remains the same and adjustments for the widening of gauge on curves are made by variations in the width of the keys which secure the pot to the tie bar. Each pot weighs 91.62 lbs., and each tie bar 26.50 lbs.; the sleeper complete, that is two pots, tie bar, keys, etc., weighs 217.47 lbs. The following table, xii, gives the weight of material required for one mile of track complete:

TABLE XII.

DETAILS.	WEIGHT OF UNIT IN LBS.		ACTUAL NUMBER OF UNITS IN ONE MILE OF LINE WITH				PER CENT EXTRA ALLOWED.	QUANTITIES WHICH SHOULD BE DELIVERED FOR 1 MILE.		
	Units.	Lb.	30 ft. Rails.	29 ft. 7½ in. Rails.	27 ft. Rails.	Assorted Rails.		No. of units.	Weight in tons.	Total tons.
Rails 30 ft. 0 in. long...	each ...	800	352	......	......	316.8	...	318	113.57	126.22
Rails 29 ft. 7½ in. long.	each ...	790	.....	356.45	......	14.25	...	14	4.94	
Rails 27 ft. 0 in. long...	each ...	720	.....	......	391.11	23.46	...	24	7.71	
Fish plates..	pair ...	36	352	356	391	356	5	370	5.95	7.40
Fish bolts with nuts ..	set of 5.	8.75	352	356	391	356	5	370	1.45	
Cast iron bowl sleepers	pair ...	183.25	1936	1960	1956	1946	2.5	1990	162.80	194.06
Tie bars.....	each ...	26.50	1936	1960	1956	1946	5	2040	24.13	
Gibs........	pair ...	.50	1936	1960	1956	1946	10	2140	.48	
Cotters	pair ...	1.04	1936	1960	1956	1946	10	2140	.99	
Inside clips..	pair ...	3.62	1936	1960	1956	1946	10	2140	3.46	
Keys	pair ...	2.24	1936	1960	1956	1946	10	2140	2.14	
Pins for rail foot	pair ...	.32	352	356	391	356	10	390	.06	
Total weight......										327.68

The illustration, Fig. 120, shows the manner in which the pots are keyed up, and also shows a detail of the rail joint used which



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somewhat peculiar in having five bolts, one of which is between the rails. The distribution of the ties is also shown. It will be seen that 11 are placed under each rail, the distance from center to center being 2 feet 9¼ inches.

The illustration, Fig. 121, shows the Pot sleeper as used on the North Western Railway with a bull-headed or double-headed rail. This is one of the largest systems in India, comprising 2,707 miles of track and owning 589 engines and 12,122 cars. This sleeper, like that shown in Fig. 119, is oval in form the length being 25 and the width 21 inches. The thickness of the metal varies between ⅝ and 7-16 of an inch and each casting weighs 92 lbs. The following table, No. xiii, gives the weight of material required for one mile of track.

TABLE XIII.

STATEMENT OF PERMANENT WAY MATERIAL REQUIRED PER MILE OF TRACK.

Number Per Mile.	Description.	Weight. Tons.	Cwt.	Qr.	Lbs.
401	23 ft. rails, 68 lbs. Per yard..................	93	6	2	7
47	20 ft. rails, 68 lbs. Per yard..................	9	10	..	27
24	17 ft. rails, 68 lbs. Per yard..................	4	2	2	8
944	Fish plates, each 11¾ lbs—2 plates to each rail	4	19	..	4
1982	Fish bolts, each 1¾ lbs., including nut and washer—2 bolts to each fish plate, 5% spare included	1	10	3	25
3718	Greaves' bowl sleepers, ribbed, each 92 lbs., 1% spare included for breakage.................	152	14	0	8
1145	Tie bars, each 30¾ lbs.......................	15	14	1	13
2405	Gibs, each 3 ounces, 5% spare included........	..	4	..	3
2405	Cotters, each ½ lb, 5% spare included.........	..	10	2	27
	Total weight of one mile of permanent way..	282	12	2	10

It will be observed in the illustration that the rail is shown resting on two wooden blocks which lie on top of the sleeper. These were put in on many roads in India with the idea that their presence would make a softer riding track, and also that rails resting on them would be in a better condition for turning than those resting on cast iron, as under the latter conditions it was usually found that the point of contact between the rail and sleeper was worn or rusted so deeply as to make the turning of the rail inadvisable if not out of the question. It was found, however, that the wood did not help the matter in the least, and at the present time these blocks are replaced by seats formed on the casting. With this sleeper the rail is held in place by a wooden wedge-shaped key driven firmly between it and one of the jaws of the sleeper. These keys are made of hard wood and hold up to their work fairly well; they must, however, be repeatedly driven up, and on some lines each wedge is driven every third or fourth day. A large number of these sleepers are in use,

but as all new rail put in is of the flat-footed type the design has been changed to receive that type.

The illustration, Fig. 122, shows the general appearance and some of the most important dimensions of the Denham-Olpherts sleeper used extensively on the East Indian Railway, which is a system of 1,843 miles, having 593 locomotives and about 11,000 cars.

This sleeper consists of a ribbed plate having a flat base and a chair for receiving the rail, cast on its upper surface. It is the custom in the use of this sleeper, as with the cast iron pot, to bury it in the ballast leaving about one-half the height of the rail uncovered.

TABLE XIV.

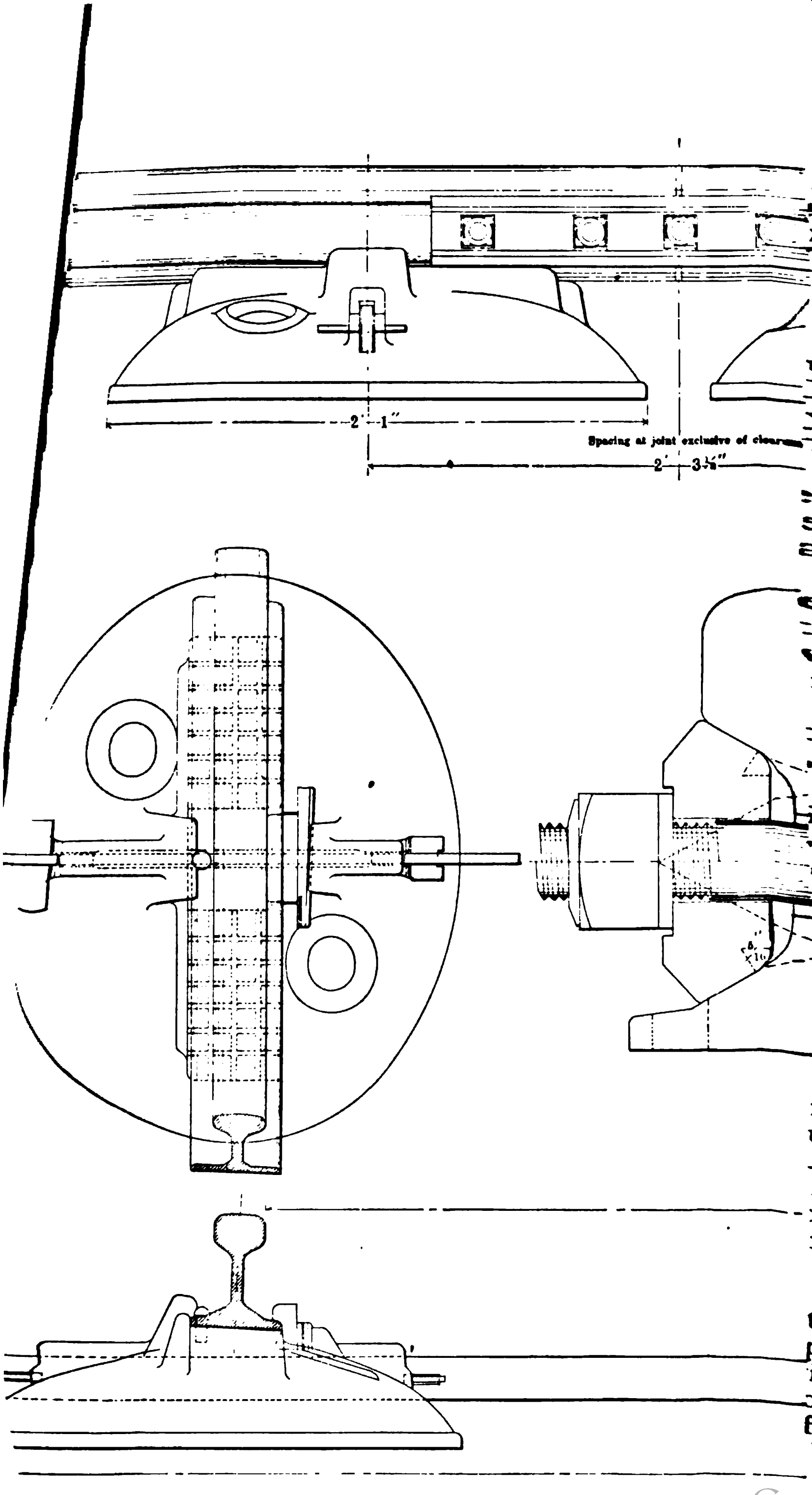
DETAILS.	WEIGHT of UNIT IN LBS.		Actual No. of units in one mile of line with	PER CENT EXTRA ALLOWED.	QUANTITIES WHICH SHOULD BE DELIVERED FOR ONE MILE.		
	Unit.	Lb.	30 ft rails.		No. of units.	Weight in tons.	Total tons.
Rails 30 ft. long.....	each...	750	352	..	352	117.86	117.86
Fish plates..........	pair ...	47.4	352	5	370	7.83	9.62
Fish bolts with nuts..	set of 6.	10.86	352	5	370	1.79	
Cast iron plate sleep'rs	pair ...	193.8	1936	2.5	1980	171.31	223.00
Loose jaws..........	pair ...	30.125	1936	5	2030	27.30	
Tie bars	each...	22.7375	1936	5	2030	20.61	
Keys................	pair ...	3.34	1936	10	2130	3.18	
Cotters	pair ...	6325	1936	10	2130	.60	
Total weight..							350.48

The Peapod or pressed steel sleeper is shown in Fig. 123, as used on the Mushkaf Bolan Railway carrying 100 pound rails. This is a government railway, and I understand that the government has adopted this type as standard for its line and laid a considerable number under seventy-five pound rails.

There is no one other subject in connection with the railways of India to which is given so much time and discussion as the subject of the comparative merits of the different types of sleepers, and of late years the most vigorous contests have been between the advocates of the pressed steel and the cast iron pot. In order to give a clear idea of the opinions held and the good and bad points of each type, I give herewith some abstracts of reports which have been made on the subject by engineers connected with railroads in India.

Note by the Consulting Engineer to the Government of India for State Railways, dated the 16th March, 1894.

Reports from various sources seem to show that the steel sleeper is rapidly oxidized and destroyed in saline soil, more particularly in Sodium Salts, and my observations during my tours of inspec-



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tion fully support this view. But doubts have been also expressed as to the durability of this sleeper under better conditions, and from what I have seen lately I am inclined to think that these doubts are sufficiently well grounded to justify another inquiry such as made by the Director General of Railways in 1889, but covering all the lines on which this sleeper is now in use. These sleepers are to be found, I think, on the following lines:

North Western Railway, Bengal Nagpur Railway, Southern Mahratta Railway, Nizam's Guaranteed Railway, South Indian Railway, Eastern Bengal Railway, and East Coast Railway; but on the last named they have been down so short a time that inquiry as to durability from that line will not be necessary. I think that close inspection will, in the case of sleepers that have been down, say, six to eight years, reveal considerable if not serious corrosion underneath, and round the edges of the lugs and at the rail seat.

If it were not for this fatal weakness, the steel stamped sleeper might be held to have fulfilled its promise of being the best substitute for the transverse wooden sleeper, while its faults, which would certainly not condemn it, are its "harshness" under traffic and the waste of metal in its tieing function, as compared with the cast iron plate or bowl. Another fault which may not be so obvious, is its lightness. The recent heavy type weighs only 135 lbs.; whereas, as I showed in a previous note, the:

Indian Midland pot sleeper weighs....................236 lbs.
East Indian railway plate sleeper weighs..............230 "
Sal sleeper weighs....................................220 "
and
Sal sleeper with chairs and spikes say..................280 "

It is now clearly recognized that a good road for heavy fast traffic must be a heavy road, both in rails and sleepers, and it is no uncommon thing to quote the fitness or unfitness of a road for such traffic by the weight per mile of its permanent way. I should consequently be quite prepared to assert that a sleeper weighing only 135 lbs., specially with rails of only 75 lbs. per yard, is too light for our standard gauge for fast traffic, the effect of which will be found in the cost of maintenance, or in rough running. I think that for high speed traffic or our standard gauge, the sleepers would not be a bit too heavy if they weighed 250 lbs. each. A sleeper of this weight in steel would clearly be of prohibitive cost, if it had no other faults, and we have to bear steadily in mind that the steel sleeper when rejected is practically valueless at present.

Thus it is time to consider, in anticipation of the result of the inquiry I have recommended above, what other type of sleeper we should adopt. My own impression, after discussion with many of our engineers, is that the average life of a steel sleeper will not much exceed twelve years, which is about the life of a good hard wood sleeper, but the wooden sleeper cannot now be

got in quantity without long previous arrangements, if even then, and the price is rapidly approaching that of the steel sleeper. As used now, our supply is limited to the following timbers: Teak, sal, pingadu, asun, deodar, and, when I say, "as used now," I refer to the possibility of getting a satisfactory design for a sleeper in which metal and wood will be combined, and in which any reasonably good hard wood could be used and less of it. This, however, is by the way. We must now recognize that the supply of wooden sleepers is distinctly below the demand, and if any new line of, say, 200 miles in length, were to be started at once, the sleepers could not under the most favorable conditions be forthcoming within eighteen months or two years. Creosoted pine from home is always a possible resource, but though cheap in first cost they are dear in the long run.

I think, therefore, that if we want a good, a heavy, and a durable road, we shall find true economy in the cast iron sleeper. In this I find I am supported by my distinguished predecessor, Sir Guilford Molesworth. Writing in September, 1883, I find, he says:

"For a metal sleeper I am inclined to prefer cast iron to wrought iron or steel. It is true that a lighter sleeper may be obtained in wrought iron or steel, but as the corrosion is much more rapid in those metals, the same durability cannot be insured in the thinner and more easily corrodible sleepers as is possible in the thicker sleeper of cast iron. Moreover, cast iron sleepers, when useless, may be remelted, but a thin wrought iron or steel sleeper, when thoroughly corroded, is valueless. I believe, too, that it has been found that if sleepers are too light, the maintenance becomes heavier in consequence of the small inertia of the sleepers."

In another note in May, 1885, he says: "I quite agree with the Consulting Engineer (Calcutta Circle) in the preference he accords to cast iron when compared with steel as a material for sleepers. I do not agree with him that steel may perhaps be equally durable with cast iron. Taking into consideration the greater rapidity of corrosion, and the smaller thickness of metal in the steel, I calculate that its durability in sleepers will probably be only one-sixth that of cast iron."

The cast iron sleeper is, of course, largely in use already on Indian railways. The bowl or the plate types are in use either partly or exclusively on Great Indian Peninsula Railway, the Bombay, Baroda and Central India Railway, the South Indian, the Madras, the Oudh and Rohilkhand railways, the Indian Midland, the Eastern Bengal, the North Western, and East Indian Railways. On the latter the plate sleeper, Denham-Olpherts, is the standard, and other sleepers (wood) are only used where they are distinctly more economical. On the other hand, the steel sleeper, which was introduced on the frontier lines in 1885, has been mostly used on State lines. It is to be found also on the Southern Mahratta, the Bengal-Nagpur, and the Nizam's guaranteed railways. In its

latest development it is under supply to the East Coast Railway, but there we are faced with the difficulty of finding a large supply of sleepers for tracts where saline soil is found and where we cannot safely use the steel sleeper.

As to the durability of the cast iron sleeper, we have ample and favorable experience. On the Madras and Great Indian Peninsula Railways there are miles of cast iron sleepers which have certainly been under traffic for 25 years and are still quite serviceable, and there can be no doubt that properly designed bowls or plates in good ballast would last fully this time. The great advantage of the sleeper is that on rejection its value as scrap is from 60 to 80 per cent of its original value, the figure varying according to the distance from the center of the demand or point where recasting can be done. Another prime advantage is that, whether in remaking or in original manufacture, the cast iron sleeper can be made in the country, and one item, not a small one, eliminated from our home remittances. The breakage of cast iron sleepers in the road is very small, but depends on the design, the ballast, and the system of packing, but on the average the figure for breakage would, I think, be about 0.4 per cent per annum.

On the other hand, the first cost of a cast iron sleeper, and certainly one of such a weight as I have indicated above, would compare unfavorably with the cost of a cast steel sleeper weighing 135 lbs., and still more as compared with timber. The relative cost of sleepers cannot be given with any degree of accuracy for the general question of a sleeper supply in India. The figures would be complicated by variables relating to supply and demand at the time, to distances of centers of supply and demand, the conditions of freight and existence or non-existence of effective competition on the part of suppliers, but a rough comparison of the cost of sleepers as now used might be somewhat as follows: Taking a hard-wood sleeper at 100, the stamped steel would be about 130, and the cast iron sleeper 155. Thus the last-named, even at its present weight, will cost considerably more at the outset than the steel, but, on the other hand, it may be certainly expected to last twice as long, and when rejected to be worth from 60 to 80 per cent of its first cost; while, under present conditions, the rejected steel sleeper will be practically valueless. Again, if we attach proper importance to the need for a heavy sleeper, and to its economy in maintenance, the comparatively light steel sleeper must be regarded unfavorably, while, if we were to increase its weight to anything like that of a cast iron sleeper, the cost would be far more than the cast iron, and it would still show the great disadvantage of having a merely nominal value on rejection.

If we adopt cast iron in lieu of steel for our metal sleepers, a few words may be given to the question of design. A very large mileage of cast iron sleepers consists of bowls, either round or elliptical in plan, and with double or single rail seats. The East

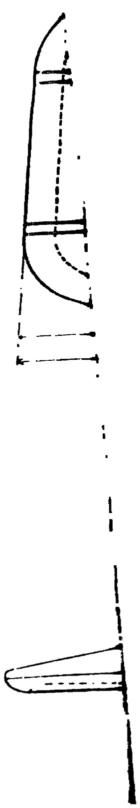
Indian Railway alone has adopted the plate or flat bottom as their standard, and in this, I think, they are right. In a report submitted as long ago as 1885 to the Railway Conference at Brussels, it was stated that European opinion might be summarized as in favor of a sleeper with a flat under-surface. In fact, as to bearing or, indeed, in any other way, the bowl has no advantage that I can see, and has the disadvantage in bad ballast of having no lateral grip, whereas the plate sleeper carries strong cross fillets for this purpose. I do not like the double seating on the oval pots as on the Great Indian Peninsula and Indian Midland Railways. It is a mistake. Theoretically, the proper bearing for the rail on a tranverse sleeper would be a knife edge.

A point in connection with adoption of a cast iron sleeper, if it is to be obtained in India, is that the manufacture can only be carried out on a comparatively small scale at present; but if it was generally known that the Government of India has adopted this as a standard for State lines, a great impetus would be given to the industry, and we might hope before long to be largely independent of supplies from England. It might also be expected that to some extent stocks of sleepers would be kept on hand in view of a sudden demand.

It will be gathered from the foregoing remarks that I think we should be more careful in ordering out further supplies of steel sleepers until we have better knowledge as to their durability, and that we cannot do wrong in substituting for these, for the present, a cast iron sleeper. The only difficulty about this is the increased first cost as compared with the steel sleeper of the present weight, and in the cost for land carriage, which would be fully 50 per cent more in the case of the cast iron sleeper. These two items, first cost and cost of carriage, are, I freely concede, very important factors in the decision and in the case of new lines, on which the prospects are uncertain, and, where cheapness in first cost is essential, the steel or even the cheapest wooden sleeper would be preferred. But for renewals on our older lines, we might safely require the adoption of the cast iron sleeper.

Note by G. H. List, Engineer in Chief, North Western Railway, India.

There is no doubt that the wooden sleeper is the best, i. e.:
1st. For ease and speed in laying.
2nd. For easy maintenance.
3rd. For good running.
4th. For "economy" of destruction in accidents.
5th. For "first cost" and cost of renewal.
6th. For general "handiness" in all temporary works.
But unhappily the supply is limited, and is getting more scarce



year by year. I doubt if it will be possible to make certain of more than 200,000 broad gauge deodar sleepers per annum in a year or two more.

The wooden sleepers chiefly used on the North Western Railway have been Deodar and Creosoted Pine, and in recent years small trial orders of the following:

Malabar teak..................................	9,732
Singapore teak	14,417
Pyingado (so called)...........................	36,197

amounting to 60,346 in all.

Our experience of these three latter has not been fortunate and I do not recommend an extension of their use. But deodar has given every satisfaction. In good ballast and under favorable conditions it has had from twenty to twenty-five years' life on North Western Railway, but the average may be taken at fifteen years. It does well in stone or brick ballast, but in sand ballast, which is chiefly used on the Saharanpur district, lower section, it does not do well, not lasting more than eight years.

Creosoted pine was largely used on I. V. S. R. and P. N. S. R. and has done well. We have still in the road a large number of sleepers which were put in in 1877. These are still quite sound in the center, and are only now to come out because they are so heavily cut into by the rail. Given a good chair or bearing plate, the life of a creosoted pine, in my opinion, should be equal to that of deodar. But it has been taken at twelve years only.

With wooden sleepers of any class I deprecate the use of a flat-footed rail as it does not give the sleeper a fair chance. Such a rail should have a heavy, wide-bearing plate giving a bearing area of at least sixty-four square inches. This should preferably be in the form of a flat chair with steel key, such as is now used for all crossings supplied from England. But my own preference is for a bull-headed rail in a cast iron chair, with outside wooden key. This is the best type of road in use, as experience has taught in England, with a heavy fast traffic, and this is the type of road we should adopt on all parts of the North Western Railway where grades and curves are severe, and the type of rail I should like to see adopted would be 84 lbs. per yard, B. H. chair 50 lbs. But the wooden sleeper is, I fear, not procurable in sufficient quantities at reasonable cost, at least not in India now. We are, therefore, driven "over sea" for wood, and, setting aside the extra cost of this, and the uncertainty of quantity and quality, I doubt if it is wise to depend on "over sea" for our sleeper supply.

The same remark applies to steel transverse sleepers, which must come from England. The experience with these has been unfortunate on some parts of the North Western Railway, especially on the Sind Sagar section under the Salt Range. No doubt some 120 miles in all, chiefly on Sind Sagar (90 miles), have failed badly from corrosion, and this class of sleeper has been sweepingly condemned.

My own opinion coincided with the general one till recently, but I have seen reason to modify my views. I have just completed a careful inspection of all the steel sleepers that have been three years and over in the road. I had one rail length in each mile taken out and carefully examined every one for

(1) Crushing in rail seat.
(2) External corrosion.
(3) Internal corrosion.

I have in preparation a detailed report on the subject, with diagrams, but this is so voluminous that it will take some time to complete. But my conclusions are shortly these:

Ninety miles on Sind Sagar must come out within three years, (forty miles of these have been done or nearly done in 1894-95 and twenty-six miles are to be done in 1895-96, and twenty-four more in 1896-97).

Ten miles in the Laki Pass, Laki to Sehwan, must come out in 1894-95 and 1895-96.

And twenty miles more between Multan and Karachi, of which five miles must come out at once, and the balance within two years.

At the end of 1893–94 there were 635¼ miles steel sleepers in the road. During 1894–95 54¾ miles were replaced by wood and 24 miles of wood were replaced by steel. At end of 1895–96, 27¼ miles more of steel will be replaced, and at the end of 1896–97, 38 miles more, so that the number of miles of steel sleepers left in the road will be 539¼, and these are at this moment as sound as when first put in and may be taken to last at least 20 years more.

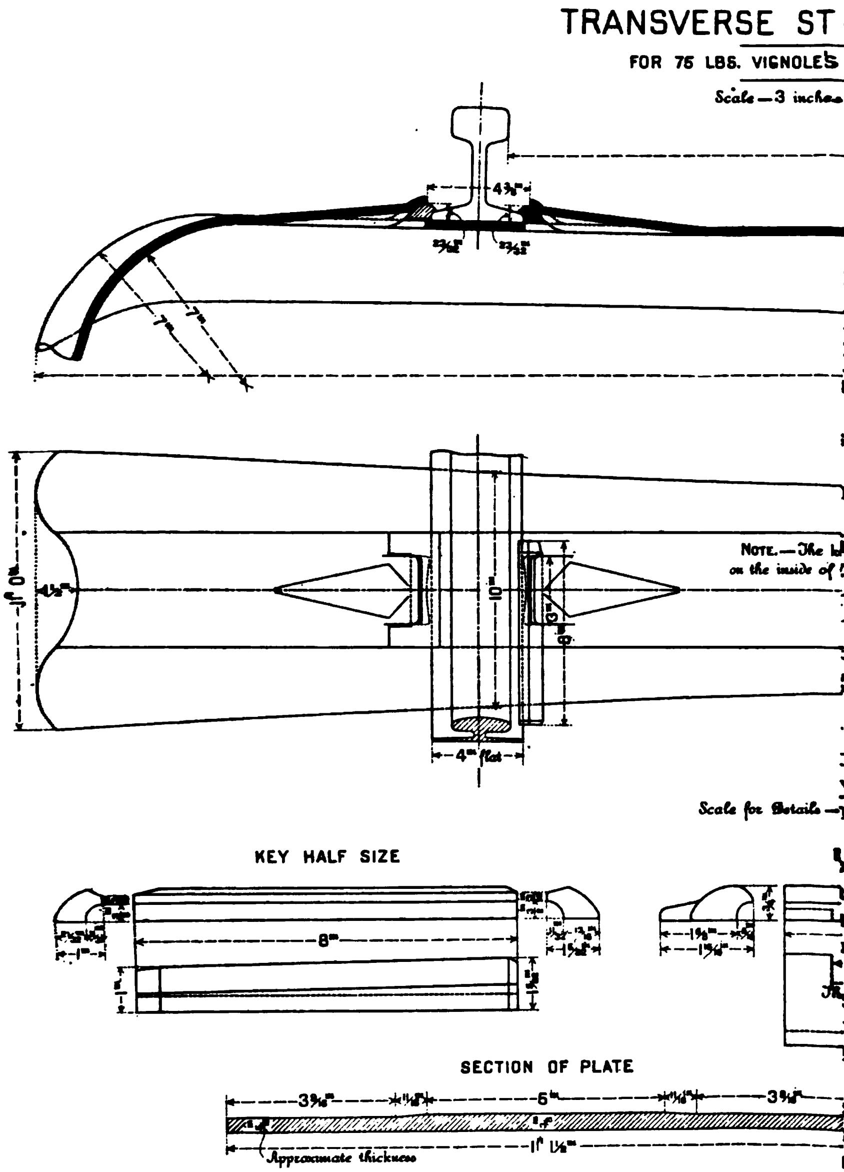
There is no doubt but that under suitable conditions the steel sleeper will give good results, but the utmost care must be taken in seeing that the conditions are suitable. These are shortly:

(1). A dry, well-drained bank.
(2). Absence of any alkali or acid in the soil which will attack steel.
(3). Suitable ballast.

It is therefore inadvisable to use steel sleepers in station yards where drainage is generally defective.

(1) Or in cuttings with a hard formation, especially rock or gravel cuttings.
(2) Or on banks that are heavily impregnated with "reh"—common salt, sulphur, or are constantly moist owing to supersaturation of the country around.
(3) Or in situations affected by the salt sea air.

Steel sleepers should not be ballasted or "blinded" with wood ashes (from Locomotive pits) nor even with coal ashes. The first is fatal in a year or two and the second is not much better. But given a dry, soft formation and good, clean, dry sand (loamy or shamp); shingle or fine small ballast and the steel sleepers stand well, and make a first-class road. It is therefore in my opinion


TRANSVERSE ST
FOR 75 LBS. VIGNOLES
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4" flat
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6"
3⅜"
1' 1½"
Approximate thickness

Fig. 1

unwise to condemn the steel sleeper outright, and in the detailed report referred to I propose noting the sections and mileages on North Western Railway where this (and other) class of sleepers may be used with advantage. But I should like to see the steel sleeper weigh at least 150 lbs. with more metal under the rail seat; and the jaws rolled on solid and not punched out.

I think a steel sleeper of this weight, with no weakening of the rail seat, and laid under conditions noted, would give a first-class, easily laid and maintained road with a life of at least thirty-five years' average. It does not make a harsh running road when laid with sand or shingle ballast, but is more or less so on stone or brick ballast depending on fineness to which it is broken. Such ballast is all too large on North Western Railway, and stone or brick ballast for steel sleepers should be broken to ¾" or 1" ring.

A length of thirty miles of steel sleepers laid on loamy sand ballast in 1888 between Sirhind and Umballa is as good a bit of road as there is in India. It is quiet, perfectly steady running, and is very easily maintained. The sleepers are as sound as the day they were laid, and there has been no crushing of rail seat, and no corrosion external or internal. The inspection train ran over this in February last at fifty miles an hour, and the absolute steadiness and noiselessness of the running was specially noticeable.

The supply of wood and steel being uncertain and insufficient for reasons given, we now come to the consideration of cast iron sleepers, the steady supply of which could be assured in India itself. The North Western Railway had at end of 1894, 343⅞ miles of cast iron sleepers in its main line section. These are chiefly of bowl pattern, oval and round, and at least fifty per cent of them were laid at first construction of S. P. & D. Ry., now over twenty-five years ago. Their life may be taken at an average from fifty to sixty years, and with a heavier type as advocated I should not hesitate to put the life at seventy to eighty years. The conditions suitable for cast iron are the same as noted for steel. But it is the wrought iron tie bar that fails most rapidly, and that is the one weak point about the bowl pattern, viz.: the difficulty of inserting a new tie bar. The difficulty, however, is not, I suppose, insuperable, and the pot sleeper makes too good a road for it to be condemned on that score. A pot sleeper road is easily laid, and, like the steel sleeper, the gauge is constant and can be regulated with certainty for curves. It is not a good road for high speeds on new banks, and takes much time and labor to get into perfect running order for high speeds. But after three years, when all is consolidated, it is perfect in all respects for ease and smoothness of running, and for silence and quietness in running, and for ease and economy of maintenance.

It has two drawbacks in my opinion, one being its great first cost, and the second being the "creep" difficulty. No doubt the first will lessen with increased demand and output. The second

can be got over by anchoring the rails either by the method adopted by I. M. R., or by putting a joint chair with a single jaw bolted through by the two central fish-plate bolts. This latter plan has been tried experimentally with good results on North Western Railway, and I have very recently learned that it is in universal use on "The Cheshire Lines Committee's" Railways in England.

My experience has been nearly all with a pot or bowl sleeper road, and I cannot say much about the advantages of flat plate sleeper. But the bowl or pot road is so good that if larger experience has shown the plate to be better, then I would at once accept the plate. We have 10¾ miles of D. O. plate and suspended 68 lb. B. H. rail near Karachi, and it is undoubtedly a first-class running road. The I. M. R. pattern pot with flat-footed rail has a very simple and secure fastening, and if a flat-footed rail is finally decided on as the type for India it could not, I think, be greatly improved on. But as stated before, my preference is for a bull-headed rail with outer wooden key. The outer key gives a cushion which much improves the silence and smoothness of running, and on sharp curves it greatly eases the flange friction and lessens the cutting of the outer rail.

The North Western Railway pot weighs 82 lbs. and is too light for our fast and heavy traffic. The I. M. R. pot weighs a little over 90 lbs., or about ten pounds heavier than North Western Railway. In the latest indents sent home for North Western Railway pattern for maintenance, and for I. M. R. pattern for double line, I have increased the weight of each pot to 90 and 100 lbs. respectively, but I should like to see it increased to 120 lbs.

The oval shape with a long bearing for the rail seems the "vogue" now. But the round pattern as originally laid has given every satisfaction and is, I think, the better type; it is certainly the stronger. Unless the pots are very carefully packed the oval pattern has a tendency to rock. The round pattern is easier to pack and gives an equal or greater area on the ballast. The long rail seat with the oval pot has, I think, been adopted to get a better support for the light rails hitherto too common on Indian heavy traffic lines. But the single central bearing (as in a chair) is undoubtedly the proper thing, and if the rail is as heavy as it should be, would allow 10 sleepers per rail to be adopted with safety and advantage.

The one great point of advantage that cast iron has over either wood or steel lies in the fact that its scrap value is so high. Old wooden sleepers sell at from 4d. to 8d. (8 to 16 cents) each. Old steel scrap at about 30 s. ($7.50) per ton and old cast iron scrap at 50 s. ($12.50) per ton, equal respectively to approximate per mile:

Wood........................	= 650 s.	($ 162.50)
Steel........................	= 2,500 s.	($ 625.00)
Cast iron....................	= 6,000 s.	($1,500.00)

But I have for long advocated that this valuable cast iron scrap should not be sold off the railway. It should all be recast into pot sleepers for maintenance. No line can do more than this at present, and supplies for extensions must come from England or Burrakur. For North Western Railway at present England works out the cheapest as the source of supply, but this may alter as the demand increases and Burrakur can be resorted to when circumstances render it difficult or impracticable to get supplies from England.

I am glad to say that steps are now being taken on North Western Railway to enable us to work up our cast iron scrap, but we should also have a small rolling mill to work up old rails into tie bars, gibs and cotters and into spikes and keys for flat-footed rails.

In this note I have not gone into details of comparative cost of each class of sleeper, as this has been very fully done by Mr. J. R. Bell and others in notes already published. I have confined my remarks to my experience on the North Western Railway as to the suitability of the various classes of sleepers in use. There is no doubt in my mind as to which sleeper is the best, and the only question to settle is, the sleeper of the future taking into consideration the question of supplies. My conclusions therefore are:

1st. The wooden sleeper should be adhered to as long as we can get suitable ones at a moderate cost, say 91 cents each.

2nd. After that comes cast iron, the shape to be adopted being decided on by experience of all types.

3rd. Then steel transverse, where price and conditions are suitable.

Each railway should note on a diagram where each class of sleeper is suitable, and this should be adhered to. On many parts of North Western Railway the use of wooden sleepers is compulsory. But on other sections cast iron or steel may be safely used.

With a wooden sleeper I should prefer to use a bull-headed rail in a heavy chair with outer wooden key or a flat-footed rail in a flat chair with steel key, as now used in point and crossings. Next in preference I hold a bull-headed rail in a cast iron pot sleeper with outer wooden key, or a flat-footed rail in I. M. R. pattern pot sleeper.

Next in preference a flat-footed rail in steel transverse sleeper with solid rail seat and jaws.

I should like now to make a few remarks on certain statements contained in Mr. Horace Bell's notes.

The steel sleeper should not be overhastily condemned without further consideration, as on the North Western Railway neither crushing nor corrosion has occurred under suitable conditions.

The steel sleeper does not make a "harsh" running road, where suitable ballast is used.

I do not think the steel sleeper need be heavier than present pattern, or at least 150 lbs as a maximum. But I would advocate a heavier rail.

The life of a steel sleeper laid "under suitable conditions" will be at least three times that estimated by Mr. H. Bell.

Its scrap value is not "nil" as supposed, but is quite 30s ($7.50) per ton in the Punjab.

The life of a creosote pine sleeper would, in my opinion, be nearly equal to deodar, if used with a proper chair or bearing plate.

I advocate that a cast iron "pot" be at least 100 lbs. in weight (120 lbs. better) to increase strength against breakage, especially in Indian make, which is more brittle than English.

But I fully agree with Mr. Horace Bell, that in first construction wood is the best; or steel where conditions are suitable; as the road is more easily and cheaply laid and is sooner got into good running condition.

That for renewals of heavy traffic lines cast iron is to be preferred (if wood is not procurable) as being like wood procurable in the country. But the question of the best sleeper to use is so intimately bound up with the question of ballast supply that no hard and fast a rule can be laid down. But generally where good, clean, dry, loamy or sharp sand or shingle or clean fine gravel can be had in great abundance, then cast iron or steel is indicated, and where stone ballast is plentiful and cheap then wooden sleepers are indicated. Curiously enough, on the North Western Railway these conditions do not always coincide with the greatest source of supply for wood.

Extract from Chief Engineer's Letter to the Agent of the South Indian Railway Regarding "Cast Iron Sleepers."

In reporting to you in 1886, on the comparative merits of the sleepers of which we then had experience, I wrote:

* * * * * * * *

• "The cast iron pot forms an excellent sleeper to which I am inclined to give, all things considered, the preference. It is not quite so free from jar as the steel cross sleepers, but it is heavier and in my opinion less liable to get out of order. We have not had more than about twelve months' experience of the steel cross sleeper, so that I am unable to testify to its powers of endurance (life), but I think that its comparatively thin material cannot live nearly so long as the thick, massive cast iron pots. In the latter we have had an experience extending over seventeen years, and the renewals due to fair wear and tear during that time have been so small as to be practically nil. They stand well in any ballast from pure sand to broken stone."

Eight years have just elapsed since the foregoing was written, and our experience during that period has confirmed the doubt expressed as to the durability of the steel cross sleepers. Sleepers of this pattern have been found on the Nellore Branch quite honeycombed with rust and unfit for use after about seven or eight years in the line, and a few have similarly failed on the Villupuram Dharmavaram Section after a considerably less service. The failure of these sleepers has been largely due to the nature of the soil on or near to which they are laid. In some instances the ballast has been mixed with ingredients of a saline nature and there the steel has gone more quickly, but corrosion has also been found where the ballast is broken stone and clean, and it is surmised that the destructive action on the sleepers is due to exhalations rising from the underlying embankments composed of chemically deleterious material.

It has also been found that these sleepers in time tend to yield under the rail seat. The top of the sleeper is here weakened by the transverse cuts made to form the raised lugs by which the rail is held in position; these lugs, when raised, leave a blank space across the top of the sleeper under the rail, where support is most required, with the result that the sleeper top yields, the rail sinks, the space between the lug and the rail increases and the steel key which should tightly wedge the rail in position becomes loose.

The cast iron pot sleeper continues to give good results, the percentages of renewals varying from .008 to .024 per cent per half year under the 68 lb. rails and from .003 to .007 per cent under the 50 lb. steel bull-headed rails between the half years ending 31st December, 1890, and 30th June, 1894.

The former have now been in the line for about 26 years and the latter for about 9 years.

The renewals of steel cross sleepers have so far been light; the sleepers on the Nellore Branch have been in the line for about 7 years and gave a percentage of renewals of 0.130 in the half yrar ended 30th June, 1894, those in the main line Villupuram Dharmavaram have been in the road for about 4 years, and the renwals in the s ame half year were .040 per cent.

There are, however, indications of influences at work under which these steel sleepers are likely to deteriorate more rapidly as time goes on, and I believe that Mr. Horace Bell correctly estimates their average life at not much exceeding 12 years.

Our experience, therefore, largely preponderates in favor of a cast iron sleeper, and I am of opinion that, all things considered, the type of pot or bowl sleeper at present in the line is the best adapted for use on the South Indian Railway system. The type sent out for trial under the 41 lb. flat-footed rail is too light, the percentage of renewals being much greater than among the pots used under the 68 and 50 lb. rails.

These sleepers weigh:

	Per pair.
Under the 68 lb. rail, each 79 to 80 lbs...........	158 to 160 lbs.
Under the 50 lb. steel rail, each 70 to 74 lbs......	140 to 148 lbs.
Under the 41¼ lb. flat footed rail, each 54 to 57 lbs....................................	108 to 114 lbs.

The steel transverse trough sleeper weighs about 70 lbs.

It would probably be found that a cast iron pot sleeper weighing about 70 lbs., similar in weight and design to the one now used under the 50 lb. steel bull-headed rail, would be economical and effective under the 41¼ lb. flat-footed rail in place of the present steel trough sleeper.

Yours faithfully,

David Logan, Chief Engineer.

Note by Mr. Street.

Each of the metal sleepers referred to in the foregoing notes has its friends and also its enemies, and arguments and discussions on their comparative merits are many and extended. The pressed steel sleeper has been attacked by some engineers, among whom is the consulting engineer to the government of India for state railways. It will be observed that the above note from this gentleman is dated March, 1894, and in February, 1895, I passed over a portion of the Mushkaf-Bolan railway, a government line which was at that time nearing completion, and noted that pressed steel sleepers were used exclusively on the work. The conditions on this line are extremely favorable for the use of this type of sleeper as it extends through a very dry, rocky section of country where rock ballast is used and good drainage attainable. These sleepers will, of course, corrode if placed in saline or alkali soil, and I have seen them in use in sections where the earth was covered with a thick white crust of lime. They were lying very near the surface with but little ballast and, as should have been anticipated when they were put in, were honeycombed with rust and the base of the rail was also badly eaten away. This should not be used as an argument against the pressed steel sleeper, as soil of this character will eat up anything in the shape of iron or steel which may be laid in it.

The cast iron pot sleeper is more largely used in India than any other type, and it gives excellent results, but it must be borne in mind that in that country the track is not subjected to alternate freezing and thawing and the resultant heaving and distortions it receives in this country. The result is that after the pot has once been thoroughly tamped and settles into position there is very little if any tendency for it to get out of line, and therefore the strain on the tie bar is slight. In a climate such as we have in the northern part of this country these conditions would be radically different, and it is questionable whether the tie bar could be depended upon to keep the track in shape. The same would

hold true of the Denham-Olpherts plate sleeper. This sleeper has developed other weaknesses which have not been noted in the paper. In tamping it has been found that if both ends of the plates are not tamped alike the gauge of the track is thrown out. That is, if the inner end of each plate is tamped harder than the outer end the gauge is widened, and if the outer ends are tamped hard the gauge is narrowed. It is stated that as much as ½ an inch variation has been made in this way. Another weakness is that if the inner end of the plate is tamped harder than the outer the tie bar will bear heavily on the plate and finally break it. These sleepers are little used and do not seem to meet with much favor.

DISCUSSION.

Mr. Hetzler: I have not prepared a discussion on the very interesting paper which we have just listened to, but have given the subject considerable thought. The reports which the paper contains are valuable, as they show us what has been done in India with metal ties. On page 272, Mr. Street in his report speaks of the comparative value of metal and wood sleepers. He states that wooden sleepers are preferable to metal, in many respects. This is undoubtedly true, therefore the question that should come before the engineers of this country is, what are the best methods of extending the life of wooden sleepers? In the report of the Forestry division of the Agricultural Department for the year 1894 it is stated that in France and Germany metal ties have been used and found unsatisfactory. In the same report it is also stated that France was obliged to import large quantities of wooden sleepers, until after they adopted a plan of chemically treating them; after this they were able to supply all that were needed from their own country. Ties in this country have been considered of too little value, and not enough care has been used in making them durable and in getting the greatest amount of service from them. The roadbed should be made more substantial by using heavier rails and not increasing the number of ties per rail length, as is often done. All ties, when subject to such usage that the rails cut into them, should be protected by plates. They should also be treated by some desirable preservative process, as by so doing they will last at least twice as long as without it. Ties are often greatly damaged by respiking, and many times through negligence removed from the track when they are suitable for further use.

E. P. Humphrey: I am not a member of your Society, but I have made quite a study of this question of metal ties while I was in the University of Wisconsin. There is one place in which the steel tie has been used in America with the very best success, and that is upon the New York Central & Hudson River Railway. The six miles from Mot Haven Junction down to the Grand Central Station at New York City, passing through the tunnel

takes all the traffic passing into New York City—I do not remember the number of trains, but the number is almost incredible that pass over the four tracks, and, not only that, there is the switching also passing over those same four tracks, so that there is a constant passage of trains back and forth. The cost of renewals, in the tunnel particularly, was so great, and so much difficulty in making those renewals, that the New York Central Railroad wanted to find something to take the place of the wooden tie, and so they experimented, first up along the Hudson River—I do not remember the name of the station now, but it was not far from Albany—with a tie that they call the Hartford tie. This was satisfactory, yet they improved on that section, which was a straight section for the entire length, by making it what I would call sway-backed. Those of you who have driven horses know what a sway-backed horse is, and this tie is pretty nearly the shape of a sway-backed horse, and this gives the tie a lateral firmness in the track, prevents it from shifting under the traffic, so that it maintains its alignment. The breadth of the tie, I think, was twenty-one inches, giving it a very large bearing area in the ballast. The ballast was filled up to the bottom of the rail and crowned in the center of the track almost to the level of the top of the rail. This tie has been in since 1885 in those six miles, and they have had almost no renewals at the time of last report, less than two years ago, and was giving almost perfect satisfaction, and they said that they expected to put in a large number additional of this kind of tie in their four-track line along the Hudson River.

Mr. George S. Morison: I have never given the subject any personal observation, but I have thought of it a good deal. There is probably no place in the world where railroads are in general use where the advantages of metal over wood would be greater than in India. There is probably no climate in the world where railroads are in general use, which is as severe on the usual railroad construction, as the climate of India. Something more than one-half of India is within the tropics and the whole of India is, in fact, a country of extreme climatic variations—for a portion of the year exceedingly dry, and a portion of the year a very excessive rainfall—all of which encourages all classes of parasitic life which destroy timber, so that not only do ties decay in India, but there is a great deal of insect life that devours them. If under those conditions it is concluded that a wooden tie is the best tie that can be had, it would seem as if a wooden tie would be the best tie anywhere else.

It must further be remembered that practically the whole of India is free from frost, so that the principal element in disturbing the alignment in American railroads is wanting there; the cast iron pot sleeper would give an exceedingly good service on the roadbed which was never heaved by frost, while on a roadbed in this country might give all the troubles that are said to exist when

a line is new. I think the general experience has been that cast iron ties have given good service everywhere in the tropics. I do not think they have been used very largely in cold climates; perhaps I am in error in this impression. They make really a very simple and very durable roadbed. I think there is a tendency now to use steel for a great many purposes for which it is not the best material. It is non-combustible, but it is not free from oxidation. Steel decays in the same way really that wood decays and in positions where there is no danger of fire, but there is often great danger of oxidation; I think we must be very cautious about using it. I have felt for some time that probably the solution of our track question was not in metallic ties, but in something approaching the English system of construction, and in saying this I know I am saying something that is generally scouted at. I know that it is of the utmost importance to increase the bearings of our rails on ties something like four times—six times would be better now, and I have never seen any method which seemed to me to promise such good results in this respect as the system of laying rails in chairs, those chairs to be bolted to the ties in a shop so that they are accurately set and the gauge is perfect.

Those chairs are made of cast iron; that was formerly prohibited in this country by its cost, but with cast iron selling, as I understand it is in certain portions of this country, for $7 per ton, the prohibition is practically removed. An objection raised to this class of construction is that a derailed train does an unusual amount of damage; instead of simply cutting off a few fish plate bolts, it may break a great many chairs. Some day I hope that we shall get rid of a great many of the appliances like loose brake beams, loose rods, etc., which cause a large proportion of our derailments, but it does not seem right to condemn a system of track when the objection to it is in the rolling stock leaving the rails, which ought never to occur.

If we were to select tie timber, not with reference to hardness, but with reference to durability, such timber as white cedar or redwood, for instance, or in cases where those could not be obtained, take ties treated by different processes, according to the soil they are to be put in; use these ties with cast iron chairs, bury the tie entirely in the ballast and lay a rail heavy enough to keep the tread something like three inches high, I believe we should get much better results with the same expenditure than we should by following the present system and using steel ties. But it must be remembered that what is all right in one location is all wrong in another. We could not use any system which would be called permanent construction, or anything very different from what we use now, on a light unballasted road in a heavy soil with very poor drainage. Without doubt any form of metallic tie, whether it be the steel tie or the cast iron tie, and any form of track in which you have a chair supporting the rail is much

more difficult to put in alignment fit for service than the form of track generally in use in this country, but when once put in alignment under the best possible conditions on a thoroughly ballasted roadbed, it will stay there and do good service. It might not, it certainly would not, do good service in a half-built roadbed.

I was asked as to the use of metal ties in this country. They have been used to a small extent on the Pennsylvania Railroad, I do not know how much. I was not aware that they had been used in the tunnel on the New York Central Railroad north of the Grand Central depot, but I have no doubt they have been. The portion of that line now in use from the end of the yard to where they have recently changed their track is in the neighborhood of three miles long. The new line is the elevated road on Fourth avenue, and the metallic structure I know is laid with steel ties and a very heavy rail, and I thought that their use there is probably evidence that the New York Central people have been satisfied with it. That whole line is a very thoroughly ballasted and a very thoroughly maintained line. It has all a special city construction.

J. W. Beardsley: The statement already referred to in the report touched upon page 273, and also the conclusion on page 277, rather led me to the view that I was about to state that certain woods will give a rapid undergrowth and develop into passable timber in a comparatively short time. Take, for instance, chestnut, I think from, say, eight to fifteen years, a second crop suitable for tie timber could be developed. Now, in ordinary timber I think that thirty ties per acre per year on an average would not be a large estimate. If we take the price that is given on page 12, ninety-one cents as a basis of the net cost, the cost of cutting and of haulage, which would probably not be more than 20 or 30 cents per tie, would leave the net cost per tie 60 cents; that for an average of 30 ties per acre would be $18.00 per acre per year as the amount saved from that source. That amount capitalized it seems to me is very suggestive as to what railroad lines could do for a permanent supply of ties and incidentally to the preservation of the forest, which is now a question much touched upon.

President Johnston: If ties could be raised at 90 cents, it would be more profitable than raising wheat.

Mr. Morison: How is that estimated price of 90 cents obtained? It is the price given as in India, now is that a gold price or a silver price?

Mr. Hetzler: There is one point brought out in the first part of the paper where Mr. Street speaks of the ties being more expensive. I had occasion to talk with our purchasing agent in regard to that and I was surprised to find out that they were at present no more expensive than ten or fifteen years ago, that is, delivered on our right of way. Several years ago there was considerable talk about the ties giving out; at the present time one does not hear anything of that and there is no trouble experienced in getting ties.

Mr. Morison: It would perhaps be worth while to state, as the paper relates to Indian railroads, that there are probably no railways in the world more thoroughly built as to ballasting and drainage than those in India. The climate has made it necessary to have the ties bedded on thoroughly ballasted roadbeds.

Mr. Humphrey: I would like to say that the chief engineer of the Pennsylvania railroad told me that as soon as the price reached $1 00 put in the track, he would then put in steel ties. The experiments they made with the steel ties, with the English bull-headed rail was a complete failure, because they could not keep it in alignment and could not keep it tamped up. That was the only experiment, he wrote me, they had made with the steel tie, and he was satisfied by experiments made on other roads that it would be a success when the proper condition was developed, and he referred me in that letter to the section on the New York Central as being an almost ideal section.

NOTE—The statement has been made that about six miles of four-track railroad along Fourth Avenue in New York City, extending from the Grand Central Station up to the Junction of the Harlem and Spuyten Duyvel lines of the New York Central & Hudson River R. R. is laid with steel ties.

A recent examination made from the rear of a passenger train shows that there are no steel ties in the main tracks between the Grand Central Station and the north end of the tunnel; it is possible, but very improbable, that there are some steel ties in the two side tunnels which are used only by local trains. There is a short reach of steel ties, possibly 200 feet long, in the south bound main track immediately north of the tunnel, which ties appear to have been in use for some time. The only lot of steel ties regularly laid along here are in the four tracks where the grade has been changed, immediately south of the new viaduct, the distance in which these ties are laid being not over 800 feet and the tracks having been in use only two months. The viaduct or elevated railroad, including the new bridge across the Harlem River, has a metallic floor to which rails are attached directly without any ties except the structural steel. The tracks north of the Harlem River, both old and new, are laid with wooden ties.

To sum up, there are in this reach of six miles 800 feet of four-track railroad laid with steel ties, which has been brought into use since the first of last March; there are possibly 200 feet of one track which have been laid with steel ties for a considerable time.

GEO. S. MORISON.

May 12th, 1897.

VIII.

THE BRITTS LANDING CABLE HOIST AND QUARRY.

By R. D. Seymour, Mem. W. S. E.

Read April 7th, 1897.

The subject of this paper is a quarry and hoist owned by the U. S. Government and operated by the U. S. Engineer Corps in Vernon County, Wisconsin. Britts Landing is on the Upper Mississippi River, about 20 miles south of LaCrosse, Wis., and before the railroads took possession of the river business, was an important shipping point for grain and cattle. The business has gone to other points now, however, and Britts Landing is not important enough to even have a postoffice. The nearest post-office is Genoa, a regular station on the C. B. & N. R. R., about 2½ miles south.

The Mississippi River in this vicinity, during the low water season, follows a meandering course through a valley about three miles wide, which is subject to overflow in the high water season. The general level of the country on both sides of this valley is about 300 feet above it, and to an observer standing on this level the valley has the appearance of being lined on both sides by abrupt bluffs. This is not the case, however, as on closer examination it will be found that the line of bluffs are broken in many places by small valleys or coulees, which give an easy grade from the bottoms to the upper level and outlets for numerous small streams which drain the surrounding country.

In making its way through this valley the river follows a very crooked course, and if it was not taken care of by the United States Engineer Corps working under appropriations for the improvement of the river, given by the general Government, would not be navigable during low water seasons. The method used in doing this work is to confine the river current by a system of deflecting dikes and closing dams to one channel and protecting the banks when necessary by willow mattresses held in place by weighting them with broken stone. These dikes and dams are easily and cheaply constructed by using the thick growth of small willows which grow on the wet lands of the bottoms, which are cut and tied in bundles. They are then woven into mattresses of any length and width desired and sunk in place by weighting them down with broken stone. By sinking these mattresses in alternate layers the dam can be built up to any height desired, and they make a very substantial structure, which resists the

erosion of the current and cause it to wash out a channel for itself and one that is sufficient for navigation. In doing this work a large amount of suitable stone was needed, and the improvements for several seasons were delayed because the officers in charge could not contract for the quantity or quality necessary to do the work. There is any quantity of stone of the required quality in the immediate neighborhood, but it is located on top of the bluffs on either side of the valley. These bluffs rise abruptly from the valley to an average height of 350 ft., and are composed of a worthless sandstone to about 300 ft. above low water mark, when the limestone formation commences and is continuous in regular layers to the top. This limestone is the stone desired, and as it is broken in horizontal and vertical seams is easily and cheaply quarried, but the difficulty in getting it to the water level and loading on barges made it very costly, as it had to be hauled in some cases as much as a mile over very bad roads before it could be loaded on barges. This method of transportation was subject to many interruptions from the weather, and in case of several days of rain the roads would be impassable as long as they were the least slippery, and the work in the river was stopped until the roads regained their normal condition. After several very exasperating interruptions of this kind the officers in charge decided to open a quarry and put in machinery to do the work. Authority was asked and granted to make the necessary expenditure, and proposals were received from different manufacturers for machinery to do the necessary work. The most available site for the quarry was leased on bluff at Britts Landing, about 750 ft. horizontally from the water's edge and 360 ft. above low water mark. The conditions imposed, when bids were asked for, were that the machine should deliver on barge in river 300 cubic yards of suitable size stone in eight hours, and that it should be so constructed as to be safely operated over the main line of the C. B. & N. R. R. The last was an important condition, as the railroad and telegraph line was at foot of bluff close to water's edge, and about three feet above high water mark. This line carries all the traffic of the Burlington system between Chicago and St. Paul, and at this point during working hours trains are run at high speed. I will anticipate a little and say here that the hoist was operated four months last season with an output of over 20,000 yards, without causing a moment's delay to any of the railroad traffic. Several schemes were proposed by different manufacturers and after due consideration the one offered by the Trenton Iron Co., of Trenton, N. J., (which was an Inclined Cable Hoist of peculiar construction and of which I will endeavor to give you a description) was accepted and they were ordered to furnish material for it. The erection and operation of hoist was done under the direct supervision of Mr. W. A. Thompson, Mem. Am. Soc. C. E., and who is the Assistant U. S. Engineer in charge of this division of the river.

Fig. 124 is a view of the bluff and hoist taken from the opposite,

FIG. 124. Bluff and hoist. East side Mississippi River. Twenty miles south of La Crosse, Wis.

or west side of the river. The distance from which this view was taken is too great to show much detail, but a good idea can be formed of the comparative elevation. The small tower shown on top of bluff is the head tower and contains the operating machinery. The lower tower can be located at water's edge in center of cut. The structure shown in front of tower is the protection over railroad and telegraph line, to protect it from possible injury. The house boats shown at right hand side are the quarter boats where quarry force was housed during working season. The clear span of this cable between heads of towers is 811 feet. The head timbers of lower tower are 70 feet above low water mark and the upper tower is 42 feet high and its head is 387 feet above the same datum. The bare appearance of the face of the bluff was

FIG. 125. View of lower tower and river from north end of quarry.

caused by the stripping from the quarry being thrown over when quarry was first opened.

Fig 125 is a view of the river taken from the north end of the quarry looking southwest, showing lower tower and river with towboat passing with a raft of timber. The cable can be seen with a loaded skip in transit. The absence of fall rope carriers will be noticed on cable, which is one of the peculiar features of this hoist, as it was operated without them. The background of the picture shows the general formation of the lands in the valley, all of which is subject to overflow in flood stages of river.

Fig. 126 is a close view of lower tower taken from the north looking southwest and showing skip as dumped on barge. These skips are made of ¼" steel and are 7′×7′×2′ in size and hold

FIG. 126. Close view of lower tower. Skip dumping on barge.

102 cubic feet. They weigh 2,000 lbs. empty, and skip and load make the total weight handled by hoist 12,200 pounds. The skip is suspended by three chains, the two side chains being equipped with ordinary hooks and the front chain which takes hold of a ring attached to bottom of skip in front with a "knock off" hook. The method of dumping skip is to lower it down to deck of barge when front hook is knocked off and in hoisting it hangs on the two side chains, dumps the load and returns to quarry in that position. In dumping the skip this way it was found that the wear on decks of barges were reduced to a minimum and the cost of repairs to same was largely in favor of the hoist.

The head timbers of this tower are 70′ above low water and the outside legs are built on a crib which serves as an anchorage for main cable. This crib is made of 8×8 pine timber and the outside dimensions are 10′×20′. It is loaded with 90 cubic yards of broken stone and cable is securely anchored in submerged part of same with two strands of 2-inch stud chain. The estimated weight of the crib and the part of tower resting on it, with water in river at the 2′ gauge mark, as shown in picture, is 140 tons. The channel between bulkhead and the crib is 32 ft. wide and deep enough to load barges to any depth needed. The barges used vary in length, but are a uniform width of 20′ and are handled in loading with an ordinary hand capstan which stands on south end of bulkhead. The material used in construction of this tower was white pine with oak for the head timbers. The shore legs are built up of 6×12–20, three pieces being used with joints 6′8″ apart. The crib legs are built of two pieces of the

FIG. 127. Close view of lower tower. Skip in position to be lowered.

same lumber with joints spaced 10'. The horizontal and angle bracing is all made of 3×12–20 spliced to make the lengths required and stiffened by the 1×6 bridging spiked on as shown in view. The weight box shown back of crib is weighted with 6,000

FIG. 128. Distant view from south end of quarry of head tower on top of bluff.

lbs. of stone and serves as a tension weight on endless or hauling line. This method of regulating the tension in hauling line, I believe, was first used on this hoist, and judging from the way it worked last season, it is a good idea where a heavy and constant stress is desired in hauling line as is necessary in this case.

In the left of this view is shown the line of the C. B. & N. R. R., previously mentioned; also the method of protecting the telegraph line, which is on the left hand side of right of way and not visible in picture. The small building shown at foot of shore legs contains the pump and boilers used in supplying the quarry with water.

FIG. 129. Close view of head tower.

The small steamboat lying outside of crib is one of the towboats used in the river work.

Fig. 127, is a view taken from same position as Fig. 126, showing loaded skip in position on cable to lower to barge.

Fig. 128 is a distant view of head tower, taken from south end of quarry looking northwest, and shows the general arrangements of tracks, etc. In the distance is shown the course of the river through the bottoms with a dim outline of the bluffs on the Minnesota side of the valley.

Fig. 129 is a close view of head tower, showing loaded skip lifted from car and ready to be sent down the cable. This tower is 16′ square at base and is 42′ high to top of sheave box. The main cable passes over the tower on substantial head timbers made by 8×10 oak, and the endless line sheaves are placed on head timbers and protected from injury while blasting by the box

shown in cut. Both parts of endless line pass over sheaves that are brass bushed and run close together on a 3" shaft held in cast

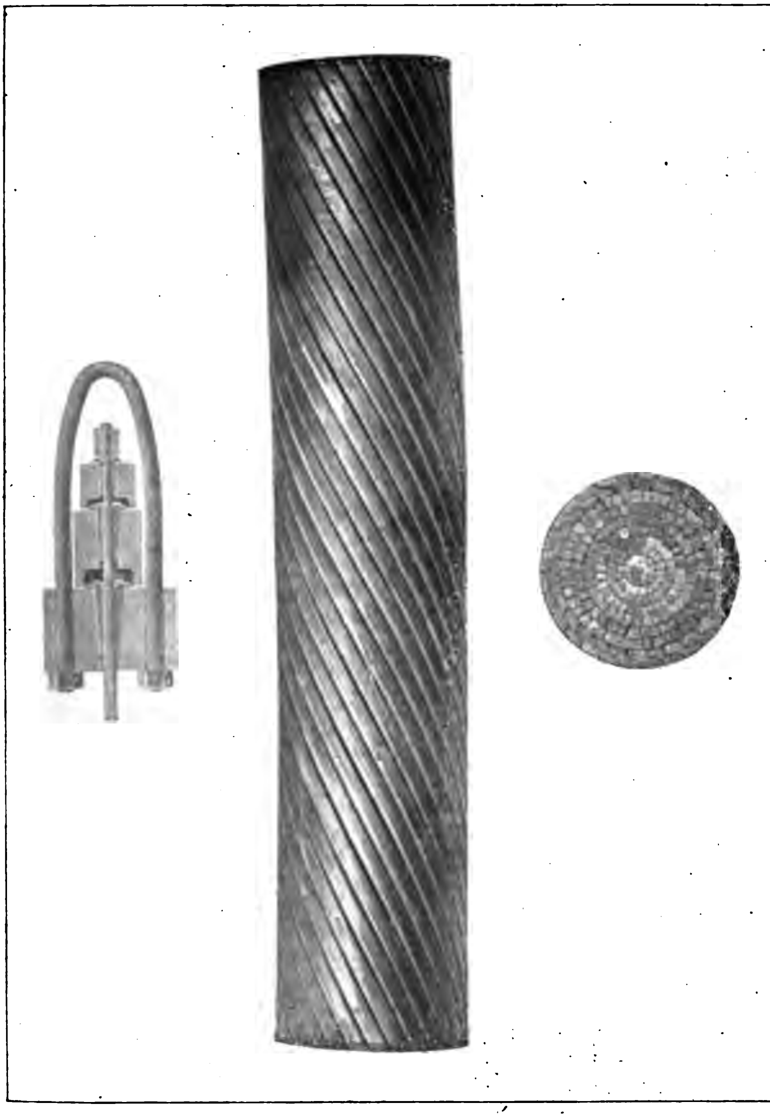

Fig. 130.

iron boxes and lines are carried down to engine drums back of tower.

This tower was built of 5×10 pine with horizontal and diagonal braces of 2×10, but when machine was started it was found necessary to reinforce it with a piece of 6×10 placed on inside of each leg of tower, and the sides were stiffened by being trussed with same size timber and 1¼" rods. This change stiffened the structure satisfactorily and no further trouble was experienced. The main cable passes over this tower to an anchorage 190 ft. back of it, on the hillside. This anchor is a 28" oak log 16 ft. long buried deep enough to insure its safely resisting the maximum pull to which it is subjected. A 2" stud chain passes around this log and is long enough to engage a loop socket above the ground that carries two take-up screws six feet long for regulating the tension in cable. The cable (Fig. 130) is 2" in diameter Patent Locked Wire Steel rope. It is anchored in cast steel "dead eyes" on both ends by patented step sockets which cause an even tension to be kept on the different layers of rope. The cut shows the details of this step socket and an enlarged section of the rope. The center of this rope is a coil of 19 wires laid up with the same twist as a strand of ordinary wire rope. The different layers shown in section of a rectangular shape are laid up with each alternate layer wound in opposite direction. The rope takes its name from the outside layers, the different strands of which are of the peculiar interlocking shape shown, and which make the outside of rope smooth and perfectly round. The interlocking of the wires renders unstranding impossible, and in the event of a wire breaking, the ends cannot project. For cableway service, this is the best rope that has ever come under the writer's notice, as it is very pliable and reduces the wear on sheaves and cable to a minimum, which makes a considerable reduction in the cost of maintenance.

The endless, or hauling line, is ⅞"–19 wire cast steel rope and the hoisting line is ¾" of the same kind.

No cut being available of the engine used, a description of it is as follows:—It is a double cylinder double friction drum hoisting engine with 10×12 cylinders reversible link motion, and is geared 6 to 1. The front drum is used for the hoisting line which passes over a 30" sheave and down perpendicularly to the engine, as shown in view. The rear drum with an auxiliary drum placed tandem to it carries the endless line. These two drums are geared together by an intermediate gear of half their diameter which is mounted on shaft and attached to a brake wheel of twice its diameter, making a very strong and reliable braking combination. It is fully equipped with all the necessary appliances for quick and safe handling, and all operating levers are conveniently assembled in a rack in front of right hand cylinder, thus enabling operator to have a plain view of both the hoist and engine. It was found that this hoist could be safely operated in clear weather without signals, but owing to the heavy fogs in the valley, which frequently effectually hide the lower tower from view, it was nec-

FIG. 131. Distant view of face of quarry, showing narrow gauge tracks.

essary to have a system of signals, and an electric signalling outfit was put in for use when lower tower could not be seen.

The stress in head of this tower, when load is in position shown in cut, is taken care of by two 1¼ guys which are anchored to each back corner of tower, and carried back at angles of 45 degrees to main cable to anchorages on hillside.

FIG. 132. Close view of face of quarry.

FIG. 133. Spring Coulee Valley looking east from top of quarry.

Fig. 131 is a distant view of face of quarry and shows the arrangement of narrow gauge tracks. These tracks were arranged as shown with a loop around the tower, the loaded cars were hauled to front of the tower, and when empty skip was returned, were then passed around loop and back to quarry face. The tracks were 36″ gauge and wheels under cars were 16″ diameter. The cars used were built so as to carry the skip as low as possible, which was 17″ above top of rail. By having the skips low, very good results were obtained, only eight men being required to load the contracted capacity of hoist.

Fig. 132 is a closer view of quarry face, showing quarrymen and loaders at work. As shown in cut the stone is in horizontal layers and having many vertical faults, it was very cheaply quarried. Small-sized Ingersoll-Sargeant steam drills were used, the boiler being located back of quarry. Owing to the peculiar situation of quarry on the edge of bluff, it was necessary that the explosives should be very carefully used as any rock thrown over the bluff was liable to damage both the boats in the river and the railroad line; for this reason the small drills were used and no holes were put down deeper than 30′—the average was about 24′. By using these shallow holes with light charges of powder and firing with a battery, the quarry face was worked back from face of bluff as shown without serious accident. At the close of operations for the season of '96 the face of quarry had been worked back nearly fifty feet further than shown in cut and the intention, when operations are resumed, is to open another face by making a cut through the floor of quarry, as shown, at right angles to face of bluff. When this is done, the cost of operation will be slightly reduced as the change will permit of more economical use of explosives and easier quarrying. The explosives used in this work were furnished by the Rend-Rock Powder Co. and electric exploders were used exclusively, no fuse shots being allowed under any circumstances. The results obtained and the entire absence of accidents serious enough to mention have made everyone connected with work enthusiastic advocates of this method.

This is the history of the Britts Landing Hoist by one who held a subordinate position in connection therewith, but before closing I would like to have one fact noted, and that is that the hoist was erected and operated through last season without there being a single accident to person or property recorded against it. It has far exceeded all the contract requirements and has fulfilled all the promises made for it as to cost of operation and maintenance, and the season of '97 will show a much better record.

Some idea of how the country in this locality looks in summer time can be obtained from Fig. 133, which is a view looking east from top of quarry hill. This valley is what is locally known as Spring Coulee and is drained by Spring Creek, which enters the river one-half mile below quarry. The tops of hills shown are the general level of country.

WRITTEN DISCUSSIONS.

By WALTER H. BALDWIN.

The Britts Landing Cableway is a successful illustration of one of the many uses to which the cableway can be applied. The use of the cableway with traveling towers, as illustrated by those which were in use on the Chicago Main Drainage Channel, in which the span was about 800 feet and loads were hoisted and conveyed up to 8 or 10 tons in weight, illustrate the cableway as applied to ordinary conditions for excavations.

There have been designed, and are now in use, horizontal and incline cableways operating self-filling buckets which will dig in ordinary sand, gravel or clay, and handle the material at a low figure. The cableway with an excavating bucket is particularly well adapted for handling placer gravel where it is desirable to deposit the material in a hopper over the sluice box, which hopper can be located in the head tower. In handling placer ground the one important question has been to dispose of the material after it has been excavated. With the ordinary steam shovel plant it was necessary to have an auxiliary plant to raise the material to a considerable height in order to run it into the sluice box and from that into the pile of tailings. Such a plant was expensive and cumbersome to move, while the cableway is comparatively inexpensive, light, and easily moved after the ground which is within reach has been cleaned up.

Horizontal cableways are now in use in many places operating in connection with clam-shell and "orange-peel" buckets for excavating sand and gravel (in some cases digging under water) for commercial purposes.

Horizontal cableways are now designed to hoist and convey loads up to 20 tons, on spans up to 2,000 feet, for the construction of dams, piers, walls, sewers, and for excavations.

The Temperly Transporter, which has recently been introduced into this country and which has been successfully used in Europe for a number of years for coaling battleships by the British, Italian, German, Austrian, French and Russian governments, and for handling rapidly light loads on wharves and docks, is a conveyor operated with a single line having an interlocking carriage, by means of which the load can be hoisted or lowered at a number of different points, and is a very ingenious device which may be classed under the head of cable conveyors.

By THOS. T. JOHNSTON, President W. S. E.

The Cable Hoist and Quarry, so well described in the paper presented by Mr. Seymour, shows so many new features in cableway and quarry practice that it deserves more than passing mention. The cableway on our drainage canal proved itself to be

able to stand the hardest kind of work, and the records made with it show some decided advantages over other methods of transporting material under unusual conditions. The hoist under discussion shows a step further, in the development of the idea, than any one has gone so far, and is worthy of careful study by those interested in handling material cheaply and expeditiously. Mr. Seymour does not tell us much about the capacity of the hoist, but I am informed that sixteen skips holding nearly sixty cubic yards of stone were handled per hour without over-working the machine or endangering the operators in any way. Considering the fact that the loads had to travel nearly the total distance between towers after being raised twelve feet above car, and then had to be lowered perpendicularly about sixty feet to deck of barge, makes this machine a decided record breaker, as I think this exceeds any record of speed made by this style of machine that has come under my notice.

The fact that they were able to work this hoist without fall rope carriers is another unique feature that deserves notice, as I do not know of any other case of an 800 foot cableway being able to get along without them. The reason of this was that, owing to the peculiar situation of hoist, the weight of the empty skip was sufficient to keep hoisting line taut and carriers were not needed. The designers did well to avoid them if it was possible to do so, as fall rope carriers are a necessary evil in cableway work that can only be avoided in exceptional cases.

The individual loads mentioned as handled in this case were not any heavier than have frequently been transported on lines that were level, or nearly so, but a case of handling them in safety on as steep an incline and at as high a speed as is shown in this plant is another new feature which deserves notice. I do not know of any other way in which this exceptionally heavy load of rock could have been lowered down an incline safely and dumped on the deck of an ordinary wooden barge, such as is used in this work, without causing very expensive repairs in a short time, but, as Mr. Seymour says the cost of repairs was in favor of the hoist, the wear must have been less than the ordinary methods of loading by hand, and I have no doubt he is right about it, as I do not think the method of dumping could be improved on.

The system of wire rope transportation, of which this machine is only one type, is rapidly coming to the front in the development of the resources of our country, and is sure to be a valuable aid to the engineering profession in the future. Compared with other methods of doing the kind of work described in the paper under discussion, the cableway has advantages that it would be well to notice. It is susceptible of being adapted to almost any combination where a clear span of 2,000 feet or less can be used, and for general utility, cheapness and simplicity of construction, it is without a rival.

Mr. Seymour does not give us any data about the cost of erection or operation, but I suppose it can be procured by any one interested by applying to the gentlemen mentioned as responsible for the erection of the hoist. I am satisfied, though, from the description of the conditions existing in this case, that the machine was installed and operated much cheaper than could possibly have been done by any other method.

The description of material used in the towers with the illustrations shows a very commendable adaptation of such means as were available for the construction of same, and prove that these towers can be easily and cheaply erected in any locality where the regular stock sizes of any kind of lumber can be obtained. The material used in this case was not the best for the purpose, but it was doubtless the only kind that could be obtained in that locality at a reasonable price, and by using larger sections than usual, very good results were obtained.

The cost of operation of hoist compared to the cost when method of getting this stone out by trains was used as mentioned in paper would have been very interesting reading, but I suppose it was left out because the cost was so much in favor of the hoist that it would have been ridiculous to have made a comparison. Mr. Seymour's paper should receive the careful attention of the membership, and he is to be congratulated on the very interesting way in which he has described and illustrated his work at Britts Landing.

IX.

ROPE TRANSMISSION.

By STAUNTON B. PECK, Mem. Am. Soc. Mech. Engrs.

Read May 5th, 1897.

Leaving out of consideration the use of wire rope, which has a limited application, there are two general ways of transmitting power by rope, usually known as the "English System" and the "American System." It is the purpose of this paper to refer only briefly to the former, and treat more particularly of the American System, which is practically a development of the last ten years, and is gaining in favor and use daily, not only in this country, but also abroad.

The English System, probably so known from its extensive employment in the mills and factories of England, has been in familiar use for a great many years. It has been by no means confined to England, and there are many notable drives of the kind in this country, particularly in New England mills and in street railway power-houses. The driving and driven pulleys are grooved and the power is transmitted by as many independent endless ropes as may be necessary. The weight of the ropes is depended upon to give the necessary adhesion in the grooves, just as in the case of wire rope transmission; but these are made V shaped, and of such size that the rope does not touch the bottom, but gets a very much increased frictional adhesion from the tendency to wedge in the grooves. Almost universal practice seems to have adopted the angle of 45 degrees for the sides of the groove as giving a sufficient grip for practical purposes, without undue tendency to squeeze the rope out of shape. It is a mistaken notion that many people seem to have that there is a loss of power in pulling the ropes out of the grooves as they leave the sheaves. With 45 degrees or with even a sharper angle, there is no appreciable disposition on the part of the ropes to stick in the grooves and follow the sheaves.

The English, or separate rope, system has certain disadvantages which are largely overcome in the American plan. Owing to the practical impossibility of getting all the ropes of precisely the same length, some of them are always doing more than their proper share of the work. This tends to stretch them and reduce their diameter, causes a differential action and slipping, all of which operates to wear out the ropes. Various devices have been resorted to to equalize the strain on the ropes, one of the simplest

being the use of grooves having slightly curved instead of straight sides. This makes the angle of the groove different at every point and equalizes the grip of the ropes which lie higher or lower in the groove according to their variations in diameter. In designing drives by this system a liberal allowance has to be made for the certainty that the power is not going to be uniformly borne by the ropes; that is, some of them will be doing more than their proportion of the work; and, furthermore, that each rope is weakened by a splice. This places the separate rope system at a disadvantage in the matter of first cost of the installation. While the splice is not of necessity a cause of trouble, it is more liable to give trouble than any other part of a transmission, and the multiplication of them in this system is not a desirable feature. The American system to all practical purposes overcomes the difficulties cited above. One continuous rope is employed, wound spirally back and forth, around driving and driven sheaves as many times as necessary, one of the wraps in its course being taken around a tension carriage or tightener. The driven sheaves may be several in number and variously located with reference to the driver as shown in Figs. 134 and 135. In the former, power is distributed to several points by wrapping all the strands of the drive successively around each driven sheave. In the latter, one or more strands, as may be needed for the required power, are used at each point. This plan requires less rope, and fewer bends in it, but the amount of power that may be utilized at each point is limited; while in the former plan it may be varied at will. The tension carriage is automatic in its action and is to the system what the governor is to an engine. It insures a uniform amount of work being per-

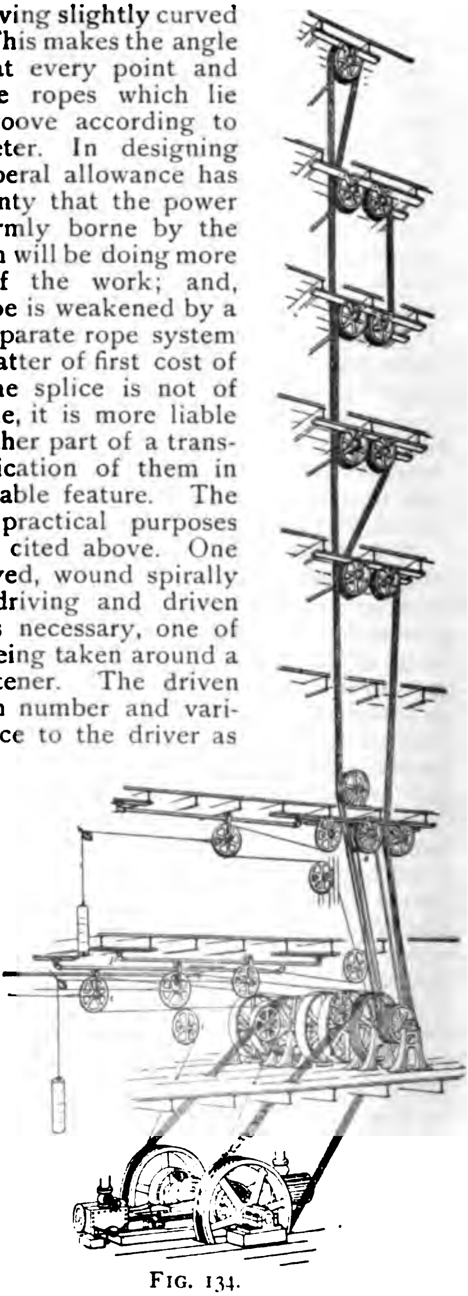

FIG. 134.

FIG. 135

formed by each wrap of the rope, and is properly weighted to give the desired driving force and to take care of the variations in length due to changes in temperature, moisture, etc.

The sheaves used in this system are grooved similarly to those previously referred to, the general angle being 45 degrees. As a matter of practice it will be observed that these are far from being so deep as in the English System; that is, the ridges between the grooves ordinarily project but a little above the pitch line, or line of contact with the rope, instead of coming some little distance beyond or outside the ropes. This may be noteworthy as bearing silent testimony to which system operates the more smoothly, as in a properly designed transmission there should be no need of a deep groove to keep the ropes from jumping out. Fig. 136 is an illustration in point where the ropes are running so smoothly and under such even tension that the 19 ropes give the appearance of one belt. It is of the utmost importance that all of the grooves in a sheave should be exactly alike and of the same exact circumference; otherwise there will be a differential action set up between the ropes. Manufacturers who make a specialty of rope transmissions should have special gauges, and devices for calipering and measuring the circumference of the grooves to insure this accuracy, but it has been the writer's observation that this most important feature does not receive the attention it should. It has been emphasized by the unsatisfactory performance of wooden sheaves, where the impossibility of preventing the uneven wearing of the grooves has caused their abandonment, after they have done much to discredit the American system of rope transmission.

The diameters of the sheaves should always be as large as convenient; it is very poor economy to reduce the first cost of a drive by using small sheaves. Forty diameters of the rope should be the rule, and thirty diameters the minimum size. It is well to observe as nearly as possible the same proportions for idlers. Even where they only carry the rope it has to conform to their circumference for the moment it is upon them. This consideration is, perhaps, more theoretical than practical, and it may be better at times, where the spans are short, to make the idlers smaller to reduce their weight and insure their keeping up to the full speed of the rope. For this same reason they should have the V-shaped groove. Round grooves in which the rope bottoms are often used but there is apt to be more or less slipping with these, especially in starting up, and consequent abrasion.

Various methods have been employed in the manufacture of sheaves, the object sought being to obtain perfectly true, uniform and smooth grooves, with the minimum machining, or without any at all. Wooden grooved sheaves have been used to a very considerable extent, and as said, been discredited; casting the grooves in chills gave great promise, but was abandoned after a costly series of experiments; corrugated steel rims have been

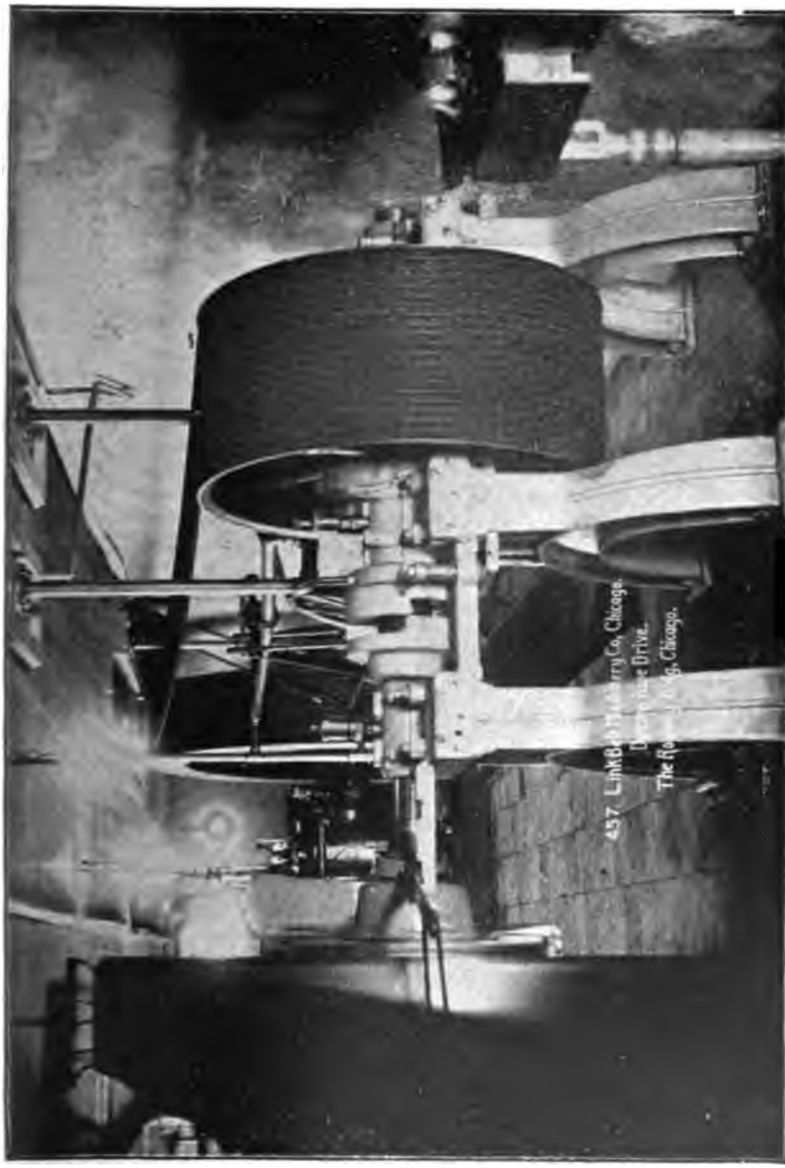

FIG. 136.

tried; and an excellent sheave has been made or "built up" of separate grooved rings bolted together, as many of the rings as necessary having arm and hubs, and being really complete single grooved sheaves. Fig. 137 shows two drives having this kind of sheaves, the driving and driven shafts in these drives being at

Fig. 137.

Fig. 138.

right angles. This type of sheave is made in a special flask, with provision for ramming the sand very compactly in the grooves, the latter coming out of the sand so true and clean that they are merely smoothed a little with emery for a finish. The best and

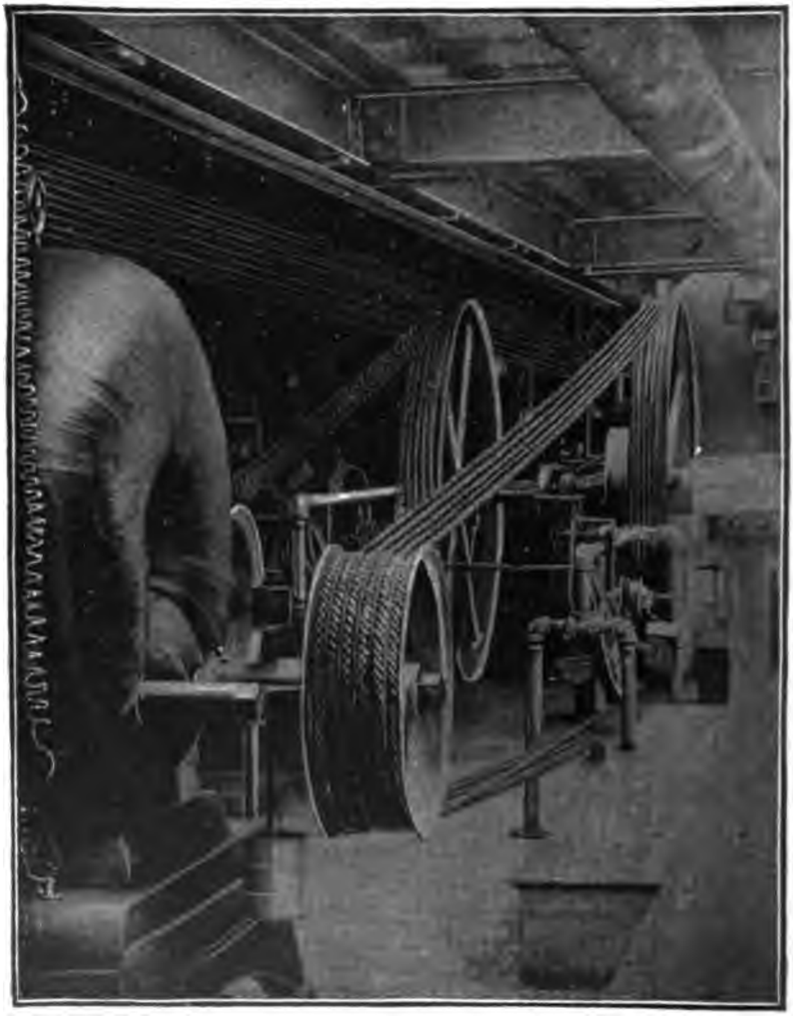

FIG. 139.

most economical sheaves made today are molded by particular machinery made for that purpose, and come from the foundry almost true and smooth enough to be used without machining, though a light cut is usually taken.

The tension carriage is a most important element of the drive. It should adjust itself automatically to the proper inclination Fig. 138 shows an approved form of horizontal carriage. It is obvious that as the rope is wound spirally on the sheaves it must be led back from the last groove of one of them to the first,

otherwise it would run off the sheaves entirely. The tension carriage sheave is set at the proper inclination to accomplish this, as illustrated in the dynamo drive shown in Fig. 139. It must take care of all the minor inequalities and variations in the sheave and rope, as well as provide the proper back-pull for the required driving force, hence the carriage should be on good-sized rollers so as to be sensitive and immediate in its action. Sufficient travel should be provided for it to take up about one fortieth of the length of the rope. This operation is often reversed, and I have frequently known tension carriages to be drawn up as far as possible by the shrinkage of the rope after a heavy rain or period of wet weather. The weight used should be only just enough to give the requisite driving force without slipping; any more than this only puts an unnecessary strain on the rope and shortens its life. The location of the tension carriage in the drive is as often determined by convenience as anything else. It may be horizontal, vertical or inclined. Two things must be kept in mind, however—it must be on one of the slack ropes, and if the particular slack rope can not conveniently be taken from the driver directly around the tension sheave, but for convenience of location must be led around the driven, or some other sheave, it must be taken around a loose groove, so that it may lead directly to the tension carriage without interference. I have frequently seen both of the above points wholly disregarded, both by manufacturers who profess to make a specialty of rope transmissions and by engineers of high standing.

The final element of transmission is the rope. In the English System, cotton ropes are generally used. This is probably from force of habit, as these drives were first introduced in textile mills, where cotton was a familiar article. It is, however, well adapted for drives of this kind, because it has comparatively little elasticity, and does not stretch, hence it is easier to keep the ropes of uniform length than with hemp or manilla. This rope is made somewhat peculiarly; it has four strands twisted together in the usual way, but each strand consists almost entirely of a bundle of yarn laid parallel with practically no twist. Each of these four bundles of yarn is wound spirally with some quite small bundles, which serve as binders and as a protection. This is what is known as the Lambeth brand of rope. It is very pliable and the friction of the soft cotton yarns on each other is less destructive than with manilla; but the latter is much stronger than cotton, and is almost universally used in the American system.

Manilla rope for the transmission of power should be made especially for that purpose. The twist should be looser than with ordinary ropes; only the longest and best fibres should be used, and selected so as to be of uniform size for the same rope. These are laid up as the rope is made, in tallow, which acts as an internal lubricant and also protects the fibre from moisture. Graphite is sometimes used also in addition to the tallow, and assists in pre-

venting internal chafing, but there is great difficulty in making the splice hold in such a rope. The best transmission rope, as shown by a series of tests, is made as above described, laid up in tallow merely, and distinguished by a red yarn running through it. Up to one inch and a quarter, three strands are used, and above that, four. The four strand rope is the better shape, as being more nearly round, but in the smaller sizes the strands are so small that they do not make so good a splice. While not absolutely necessary, external dressings applied at intervals to the ropes are desirable, especially for out-door drives, and where the rope is exposed to a hot, dry atmosphere. These dressings are made of varying proportions of such ingredients as tallow, graphite, pine tar, linseed oil, cotton-seed oil, molasses, rosin, etc. One very conveniently applied dressing is made in the form of sticks about 18 inches long and 3 inches in diameter, which are held against the rope while it is running, as shown by Fig. 140.

Fig. 140.

Ropes of rawhide gave great promise a few years ago, and a number were put in use; most of these have been replaced with manilla. Rawhide rope has great flexibility, and having comparatively few strands is better able to stand internal and external friction, as there are no small yarns to chafe and break. Its most frequent use was for dynamo drives and where small sheaves were necessary. The great elasticity causes a good deal of whipping and slapping, and it is very difficult to make a splice hold; furthermore, the first cost is several times that of manilla, and as it has not shown a proportionately greater durability to justify this, it is probable rawhide will never be used to any great extent.

As I said above, the splice is the weakest part of the drive. Correctly made, however, and in a properly designed drive, it should never give any trouble. As a matter of fact, much of the trouble caused by the failure of splices is due to the prevailing notion that any kind of a splice will answer. The ordinary sailor's splice, or the short splice, which is perfectly satisfactory for hauling or hoisting ropes, is quite inadequate for transmissions. The splices suitable for the latter are variously known as the English splice, or the long splice, and are from 80 to 150 diameters

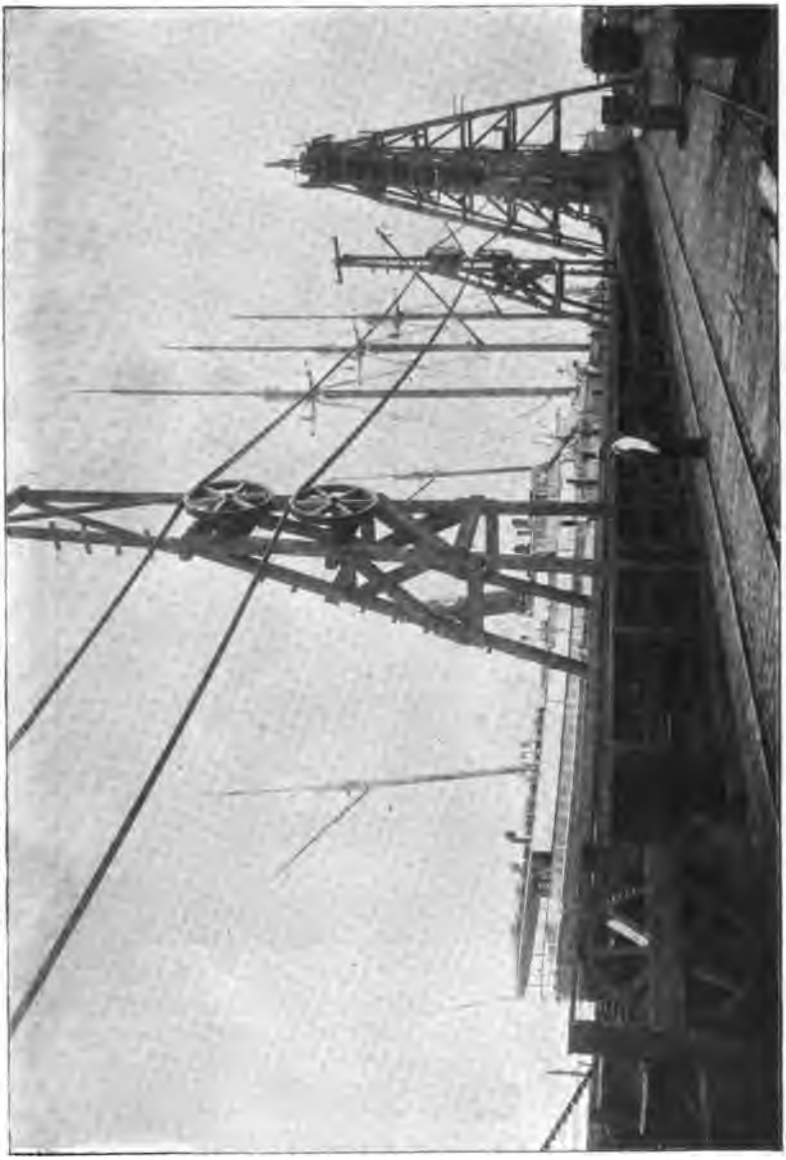

FIG. 141.

of the rope in length. Various mechanical splices have been tried, but most of them have had a very limited use. One objection to them is that they give way without warning, whereas the ordinary splice usually attracts attention by beginning to unstrand in ample time to prevent any damage.

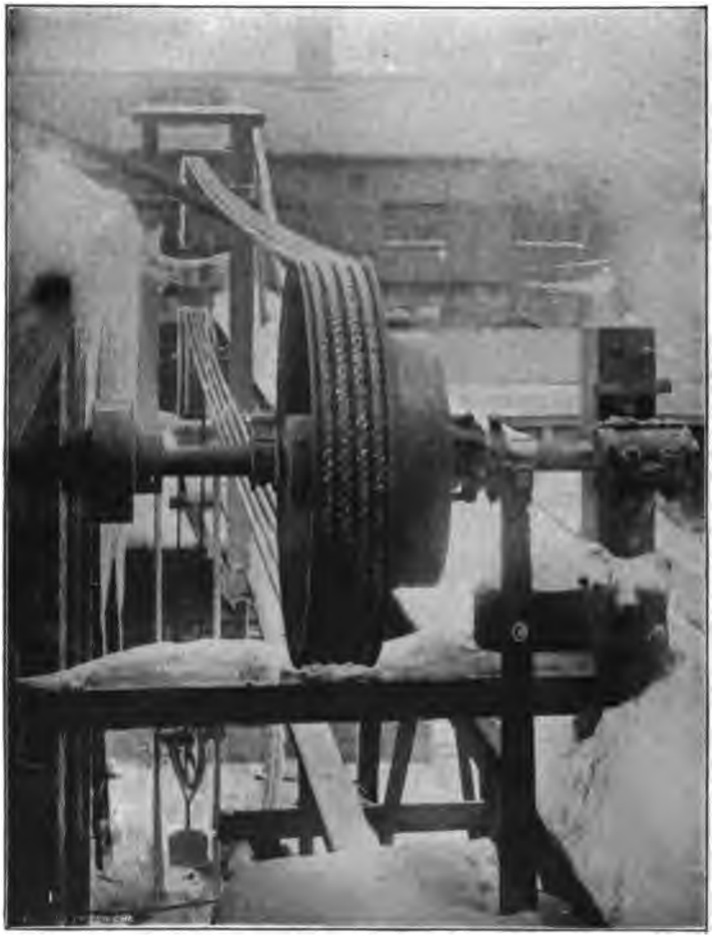

FIG. 142.

Leaving the subject in its details and considering its general application, the availablity for long transmissions, and especially for out-door drives, is at once apparent. Figs. 141 and 142 illustrate drives of these kinds. The latter transmitting 40 H. P., has run daily for several years, and was entirely unaffected by the six weeks of unusually severe winter weather in 1895 when the view was taken. By the use of rope the highest economy may be secured in large manufacturing and industrial establishments, as it becomes possible to distribute the power from one central power-house. It is unnecessary before this society to dwell upon the desirability of such an arrangement as compared with the old way of having engines, and perhaps boilers, scattered all over a

FIG. 143.

FIG. 144.

plant. Fig. 143 shows the interior of a power-house where 100 H. P. each is delivered by ropes to two jack shafts, from whence it is still further distributed by several smaller rope drives to various parts of the plant. In Fig. 144 the engine is in the basement of building not shown, to left of the cut. The power is carried

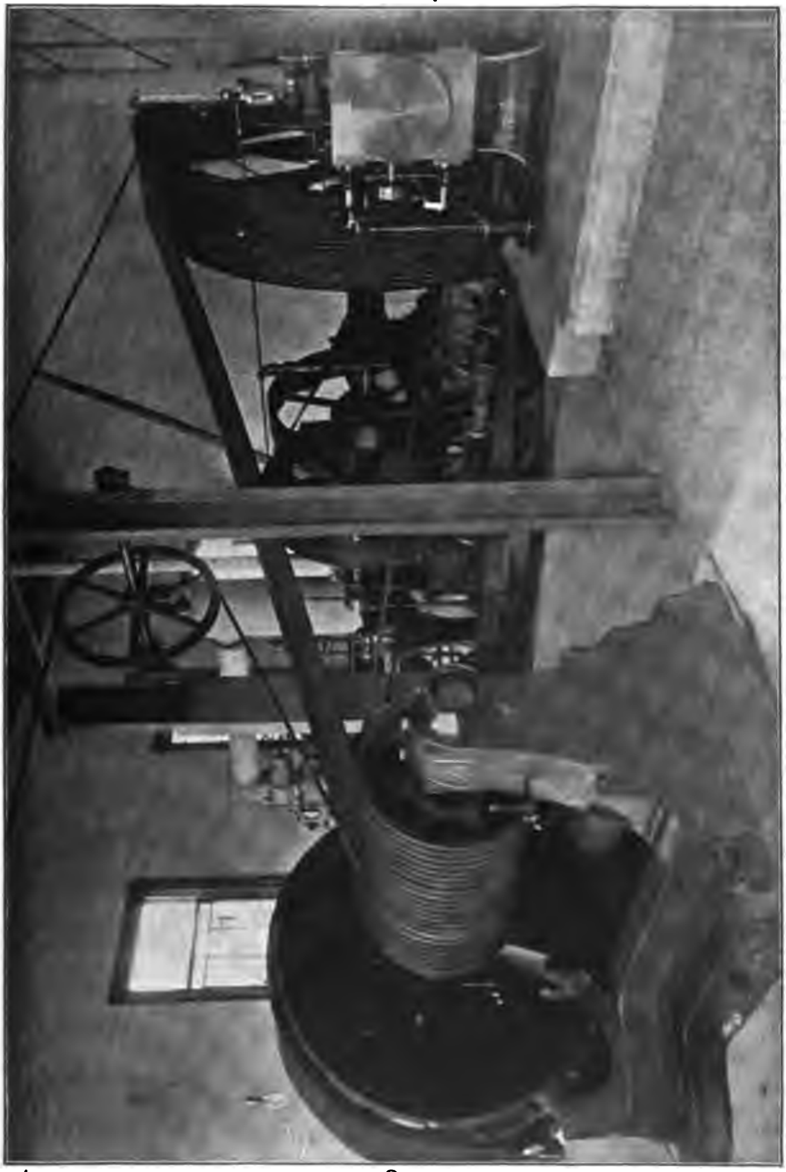

Fig. 145.

up through the roof, across the alley and down, where a portion is transmitted to a line shaft projecting through first building shown in cut, and the balance carried on to the building shown on the right.

FIG. 146.

In vertical drives, and in main drives from the fly wheels of engines, it is well known that there is excessive journal friction from the tightness at which belts must be kept in the former case, and from their great weight in the latter. Much of this is saved by the use of ropes, beside the advantage of a much quieter and

Fig. 147.

smoother running drive. It is not at all uncommon to find fifteen or twenty per cent of the power absorbed by journal friction and the stiffness of heavy main belts. A properly designed rope drive of the American system does not absorb more than four or

FIG. 148.

five per cent. As it is not good practice to require a single tension carriage to take care of more than about eight or ten wraps of rope, these main drives are usually made up of two or more drives side by side exactly alike, each having its own rope and

tension carriage. Fig. 145 shows a 300 H. P. drive made up of three separate 100 H. P. drives, of 7-7/8″ ropes each, and each drive having its own tension carriage. Another plan sometimes employed is to wind the ropes in pairs, treating a pair of ropes precisely as though it were a single rope. Although there are some successful drives running in this way, this plan is not to be commended, as the two ropes on the tension carriage do not permit it to properly control either. An advantage of dividing main drives as noted above, is that a portion of them may be run independently, or repaired while the balance of the drive is running.

In crossed, quarter-twist and mulestand drives, the flexibility of rope and the ease with which it may be led around the corners, make a very appreciable saving of the large percentage of power that is wasted in overcoming the stiffness of belts under similar conditions. Figure 146 illustrates a drive between two shafts at right angles, and running around a mulestand. The shafts run at different speeds so that the driver and driven are of different diameters and the idlers are set at the proper inclinations to lead the ropes fairly. Figure 147 shows a method of reversing the motion of a rope, or the equivalent of crossing it. The view is taken in the lantern of a large grain elevator, and shows drives to the heads of the elevators on either side of the line shaft. The elevators on the right turn in the same direction as the line shaft and are driven with ropes in the ordinary way. On the left-hand side, where the motion of the elevators is the opposite of the line shaft, the rope does not encircle the driven sheave, but the reverse or inside of the ropes is held against the driving sheave for half of its circumference by the idlers above and below it. It is entirely practicable to reverse motion by actually crossing each strand of rope; that is, by leading successively from the under side of one sheave to the upper side of the other, and vice versa; but the sheaves for this kind of a drive must have sufficient distance left between the grooves so that the ropes can pass each other between the sheaves without coming in contact and sawing.

Freedom from slipping makes rope particularly suited for dynamo drives for electric lighting, assuring a steadier current. I recall in this connection an incident where the basement of a large office building was partially flooded by continued heavy rains. Several of the dynamos were driven by belts, and were at once rendered inoperative, while those that were driven by ropes gave uninterrupted service.

The speeds at which ropes are run range from 1,000 to 5,000 ft. per minute. I have known of drives running successfully as high as 8,000 ft. Above 5,000 ft. a little figuring, using the ordinary formula, will show that centrifugal force tending to throw the rope out of the grooves, becomes an important factor. Experience would seem to show, however, that practically it does

not act as rapidly to diminish the driving force as it is theoretically supposed to. Its action can be counteracted by additional weight on the tension carriage, so that I have no doubt but what successful transmissions could be employed at a rope speed as high as 10,000 ft. per minute, or more, although the wear of the rope would be rapid. The best speeds are from 2,500 to 4,500 ft. per minute.

The use of winder sheaves is occasionally resorted to to give additional frictional adhesion, at both driving and driven ends of a transmission. That is, the rope in passing from driver to driven is wrapped one or more times as may be necessary around another sheave near the driver before being led around the driven, and wrapped around a similar sheave near the driven, before returning again to the driver. This is done in the drives in Fig. 137. It is a familiar device employed in all cable street railways. The advantage derived is not as great as might appear at first sight, as the tax upon the rope is greater from the frequent bending, and from the increased strain put upon the fewer number of ropes that transmit the power. This device may be used to advantage, however, in very long transmissions, as it reduces the amount of rope and the number of grooves in the carrying idlers; and also in drives where there is a great disparity in size between the driving and driven sheaves. I have in mind a successful transmission in an electric lighting station where the driving wheel is an engine fly-wheel 20 feet in diameter, and the driven sheave but a short distance away, 34 inches in diameter. The loss of arc of contact on the driven sheave is compensated by wrapping the rope four times around each of two re-winders at the driven end, giving the driven sheave practically 20 grooves to 12 in the driver. In drives of this kind care must be taken not to place the rewinder too near the sheave, as there may not be sufficient elasticity in the strands of rope to equalize the differential action set up by the unavoidable inequalities in the size of the rope and the grooves of the sheaves, and an excessive strain is produced on the shafts. The writer was once called upon to examine eight drives, about 300 ft. long each, where the power was transmitted by two 1 1/8" ropes and six wraps taken around a winder at each end of each drive. These winders were set so close to the main shaft that several of their shafts, which were 3 7-16" in diameter, were broken and all more or less badly sprung. A somewhat similar experience was met with by parties endeavoring to drive a street railway car by wrapping a continuous rope from sheave on central armature shaft six times around each axle and finally around a tension carriage. It was found that while the truck could be readily pushed by two men: with the ropes on, it took about 40 H. P. to move it.

There are three questions that are constantly asked about rope transmissions; what powers will the various sizes of rope transmit at given speeds; how long will the rope last, and what is the

cost relative to other modes of transmission. Unfortunately, a clean-cut, decisive answer cannot be given to any of them. There have been tables published giving the horse-powers of different sizes of rope at various speeds, but none by any one who has had the experience that would make such a table reliable. Many things have to be taken into consideration in designing a transmission. Large sheaves and a few wraps of comparatively large ropes should be used in preference to small ropes and many wraps. Excessive speeds, reverse bends and frequent turns should be avoided as far as possible. In no small number of cases, however, the exigencies of the situation necessitate some one or more conditions that are unfavorable, and it is obvious

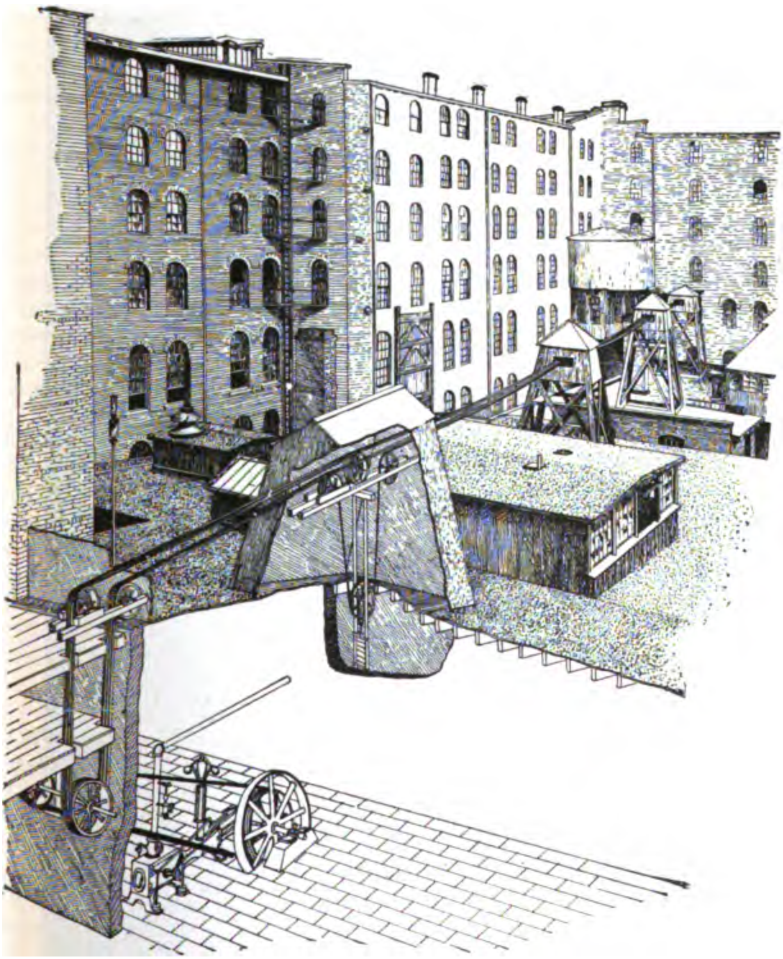

Fig. 149.

that the work demanded of the rope should vary, as experience has shown the conditions to be more or less unfavorable. As an average illustration, however, of its transmitting power, it may be said that under ordinary conditions and at a speed of 2,500 feet per minute, 1" rope will satisfactorily transmit 12 horse-

Fig. 150.

power, 1-½" rope, 26 horse-power, and 2" rope 48 horse-power. It must always be borne in mind that the durability of the rope must be kept sight of as well as the actual transmitting power. This varies very greatly. Drives put in on the English system, using cotton ropes, are numerous where the ropes have lasted ten to twenty years. These drives, however, all have ropes two inches or more in size, and very large sheaves proportionately. It may be said that the average life of ropes of medium size is upwards of five years. A great many that were put in more than five years ago are still giving good service today, so that as a matter of fact, the system has hardly been in use long enough to determine what would be a fair length of service to expect. The small ropes under unfavorable conditions, often have to be renewed annually. I know of one concern running a ¾" rope at high speed on a 9" sheave, who put on a new rope every three weeks, yet are perfectly satisfied with the transmission, which is the most successful means ever found to accomplish the purpose.

In the matter of comparative cost of rope and other transmissions, it can only be said that the grooved sheaves are considerably more expensive than plain pulleys, and there is the additional cost of the tension carriage: while on the other hand rope is very much cheaper than belting. From this it can be inferred that short drives of belts are the cheaper, while long drives of rope have the advantage in first cost, and increasingly so as the distance between centers increases. Again, with heavy main drives, from fly-wheels to jack shaft the large leather belts are so expensive that even with comparatively short centers the rope transmission is the cheaper.

I will only add in conclusion that rope transmissions should be designed with intelligence, and judgment based on experience. Where this is done they are certain to prove efficient and economical. The idea that because a rope is so flexible and so simple a thing it is bound to run all right, no matter what is done with it, is a mistaken one, and is largely responsible for any mistakes that may have been made, or prejudices created against this most modern and satisfactory means of transmitting power.

DISCUSSION.

Mr. John Walker: My experience in rope driving dates back over thirty-five years. I want to correct one impression that is given in the paper, that the so-called American system is not strictly an American system; it has been in use in England thirty-five years. It is like so many other things that have been re-invented or re-introduced. To prove what I say, the Craven Brothers of Manchester have made traveling cranes for forty years, with rope drives of the very same system known here today as the American system I point this out to show that we may get a little at

fault at times by people unintentionally ascribing things to countries and places as new when they are really not new—I mean, not new to other countries.

We take rope driving in all its phases, it is a European introduction or invention. It was first brought out, I believe, in Belfast, and, as has been stated by the writer, used largely in the cotton mills, and the ropes in that country were made mostly of cotton in the early days, because that material was most convenient for them and easily made.

It is true the separate rope system was used to such an extent in England that it became known as the English system; it suited the conditions of cotton mill driving in which it was and is still used so extensively. Hence the names English and American systems come from the use of the separate ropes in England and the continuous rope in America. So much for the two systems.

I have the pleasure of knowing Mr. Hart. He is the inventor of the Lambeth make of rope spoken of here; he has large works in Blackburn, near Manchester, England, and they are now manufacturing the same kind of rope at New Bedford, near Boston, Mass.

The different methods of compensating for the difference in arc contact of the two pulleys, i. e., large and small, has been mentioned. The Miller system of making the grooves of different angles is about as simple a system as I am aware of. He makes a groove of more acute angle for the smaller diameter pulley, and makes the groove less acute for the larger diameter so that the effect may be about even in the two pulleys. This I may say is not new, although applied as he has done it so effectually and taken up as a commercial matter, he deserves a great deal of credit. I think he makes the grooves of the smaller pulley thirty to forty-five degrees, while the larger pulley may be forty-five to sixty degrees, according to their diameters.

There have been different methods gotten up for regulating the tension on various ropes; the English system, as we know it by the paper, requires something in that line. The writer tells us of different methods and speaks of the grooves in a different form. I would like to mention one at my own that is making pulleys with differential rings. Those of you who have seen the Walker Manufacturing Company's catalogue have seen the differential pulleys illustrated there. It is intended the small pulley only will have differential rings for each rope, when each of the grooves are independent, and there is an unequal tension on any one of the ropes, and consequently on the rings, they will accommodate themselves at once to the inequality, they will automatically adjust themselves at any time when the power becomes different on any single rope.

Exception has been taken to the separate rope system on account of the number of splices. I do not consider that well taken, neither do I consider the splice on the rope necessarily the

weakest place. I have known cotton ropes working for twelve and fourteen years and the splice did not give out. As was mentioned here, a good long splice is necessary; our rule used to be something like 144 diameters, consequently an inch rope would take a twelve-foot splice, and if it is properly made there is no question about its lasting.

Another feature, I think, is commendable in the separate rope system; that is, if one of the ropes breaks you need not stop the machinery to put another rope on, whereas, if the continuous rope breaks, the entire machinery must stop.

There has been a very good suggestion made in the paper, instead of making the drives with a single tension carriage, the writer very appropriately suggests that the entire plant need not stop if divided into a series of continuous ropes. In this particular, if it is good to divide the continuous ropes, there can be no objection to individual ropes. I am not a believer in small ropes; I would rather have larger ropes and ef wre of them, and thus lessen the number of splices. Larger ropes also means fewer wraps for a given power, hence, less tangents, which means less number of times bending the rope. In some drives where we have six wraps in a continuous rope, one larger rope might answer the purpose in making one round, the continuous rope will make twenty-four tangents or bends while the other will make only four. Good judgment and experience are necessary in sizing these things up. I think there has been great error made in this country in using ropes of too small a diameter. It is quite clear to me that the fewer turns and reverses in particular you have in your rope, the better it will be for the life of the rope. Take a piece of wire, first turn it one way and then the other, that is the way to break it, and so it is with everything else. In regard to this method of reversing the motion of a shaft, I must say I do not like it; I would rather reverse it in any other way than torture the rope by so many reverse turns. I do not suppose it is adopted by preference and should think it would be avoided whenever possible.

In regard to wooden grooved pulleys, when first introduced I had occasion to examine a continuous rope drive in Cleveland; I found some of the grooves varying as much as an inch and a half in diameter on one pulley on account of wear; it was impossible to keep the rope from breaking until iron pulleys were substituted.

In regard to the idler sheave, I should think the question whether you use a round bottom groove would be immaterial, but if there is any great strain on the idler, I should prefer a round bottom groove to fit the rope because you would then be giving the rope some support and help keep it in shape where you had the opportunity.

Speaking of the form of groove, some years ago I took notice in one of the cable power houses, I think it was in Baltimore,

where the rope had taken a set, that is, it was wearing itself in the shape of the groove. I have not seen more than three such cases in all my experience; my experience has been that ropes revolved and rounded themselves up in passing over the pulleys. The thought has occurred to me that sometimes men putting in ropes do a thing they ought not to do, that is, take the twist out of the rope before splicing; I think they should leave it in; I have always had my ropes put in with the twist left in. I have never found a rope yet that was put on in that way that took a set. What I mean by a set is that the rope stops revolving as it passes over the pulleys. The ropes in question were wearing themselves V shaped, which is a serious matter, because the wearing takes place only on one part of the strand forming the rope, the other part of the strand not being worn at all.

At the Walker Manufacturing Company in Cleveland we made a comparative test between cotton and hemp ropes by installing at the new shops six cotton ropes and six hemp ropes running together, all 2" diameter and of the same length. To my surprise the cotton ropes lasted only half a year. It was rather a tortuous drive, too short for good practice and had one idler near the receiving pulley which put a slight reverse bend in the ropes. The cotton and hemp ropes were of the ordinary four-ply, the latter made by Hunt & Co., of New York. They were still working satisfactorily when I lef tthe Walker Manufacturing Company, after running about three years; could not say how much longer they lasted. The cotton ropes, however, did not last more than half a year; they got quite fuzzy, became enlarged, notwithstanding they were well taken care of and well filled with graphite and molasses. In this case all the conditions were the same, all the ropes were on the same pulleys and subject to same treatment, hence the result must be accepted as showing the relative value of the two kinds of rope.

I should like to ask one question. In the general design of this machinery is it planned to get the grooves of the different pulleys in line? It seems to me, while it is not very important in these long stretches, yet there would be some side strain and friction in short stretches. Cable railroad drums which are wound in the same manner were formerly tilted to bring the grooves in line, but of late years they were made level and grooves staggered; that is, the center of grooves in one drum would be opposite a center between the grooves of the other drum, thus averaging the grooves and consequently the lead at top and bottom of the drums; this might be used to advantage in continuous rope drives.

There is a remark made in the paper about the old-fashioned grooves, or the original grooves being very deep and consequently objectionable. I think that does not apply to the separate rope system at least. Also, I do not know why a well arranged, properly conditioned, separate rope system should have any deeper groove than the continuous rope system. Of course, I understand

the ropes have the slack taken up by the tension carriage in the continuous system. I think a deep groove is simply a matter of judgment and not a necessity. Some of these things get started in a certain part of the world and they are more or less copied and pass on from one generation to another. I mention this because cable drums formerly were made with deep grooves with the idea that when a slight slackness in one of the wraps occurred the cable might get off and become tangled up. Recently the practice is to make them only half a circle, the rope lies on the groove and does the work just as well. Deep grooved rope pulleys is likely to aid the ropes in riding just as flanges on pulleys often cause a belt to ride on them; experience has taught us that a pulley with extra or double the amount of crowning is better than flanges forkeeping a belt on.

I am not aware whether the writer meant in his paper what is known as the compound Hoadley Bros. winding system. However that may be, I want to say a few words on that system while we are talking about rope drives, and I think there is rather a fallacy in connection with it. For instance, we take the smaller pulley and make several winds to an idler pulley and shaft. In one case in this city I saw something like 10 laps in one of these compound drives. It only requires a moment's reflection to know that all you have got where the rope leaves the driving pulley to take the wraps on the idler is the strength of one rope. So what is the use of this additional winding on the idler pulley? Any additional lap that is made on the idler pulley simply tortures the rope. To illustrate, take any rope that is passing from a straight line to a circle and from a circle to a straight line; if you have ten wraps it means twenty windings and twenty unwindings of the rope, which to my mind is a very serious objection, especially when you have only the strength of the rope in passing from your driving pulley to your compound winding. The same thing may be accomplished with additional tension on the carriage, for if you have the working strength of your rope there is danger in having any more, and if you have not sufficient, then add more tension weight on the carriage until you get the working tension required, which is certainly simpler than adding useless wraps to drive an idler pulley and shaft, to say nothing of the power lost to drive same and the increased length of the rope, the many tangents bending and unbending the entire rope or ropes in passing over this useless idler to gain an imaginary benefit.

The writer speaks of a case where the tension carriage had been brought to end of its runway (page 309) on account of the driving rope being wet. Where one tension carriage has to take care of a large quantity of rope, it is very apparent that the sameis objectionable, and if the rope is so long that it shrinks on account of being wet that all the tension run is taken up, and the tension carriage anchored tight, the reverse is true when the rope is dry,

hence the division of ropes into reasonable lengths becomes a necessity.

In regard to horse-power of ropes, I intended, before coming to the meeting, to get some data gathered from European factories, some that I formulated many years ago and some that has been sent me since and that can be relied upon. There is no question at this date, after all the rope driving systems have been put into use, both separate ropes and continuous ropes (when the conditions, of course, are considered as being fair conditions) but that the horse-power can be gotten at and coefficients determined to suit any kind of rope that has been used. Their lives, of course, would simply be a matter of conjecture. The best rope that I have had brought to my notice, that is, so far as the manner of making it was concerned, was very ingenious. I think it was brought to this country by some manufacturer of Manchester, England. He had so arranged his strands and core and they had been so twisted that they were almost of even length. If you take an ordinary driving rope and cut it in two, take out, say, an eight-inch section and unwind the different strands and core and lay them out on the table, the outer strands of the rope would be considerably longer than those forming the core, showing that there would be unusual strain in the shorter parts when the rope was in tension, or that the parts forming the twist, when pulled straight, would be that much longer, consequently the straight strands were getting tension earlier than the twisted strands. His object was to get all the strands and core as near one length as possible. I have not heard of this rope since; that was about two years ago.

I would like to ask the writer if in the drive referred to on page 319, the second paragraph, where he speaks about the basement being partially flooded, the rope was actually run in water.

One more point I wish to take exception to; I do not believe in ropes of 10,000 ft. speed per minute. They would not stay together long, that is certain. I think it would be well to correct this statement so as not to be misleading to the next generation. We all understand that every material has certain strength and at certain speeds looses its cohesive strength. This is true of ropes, belts, etc. Another instance, our cables on street railroad work are very satisfactory where they are, and are propelled and bear on the sheaves every 32 feet, but you take one of those cables and pull one end vertically into the air, it will break before the other end gets off the ground. There are different conditions of things, in one case useful, in another, useless. It is so in a case like this where a question of reasonable speed is satisfactory, and at an unreasonable speed the thing will disintegrate; it will not hold together. I don't think it is possible to pull an ordinary transmission rope through space at a speed of 10,000 feet per minute without being torn asunder, even allowing it to start as slowly as possible from a state of rest. As the writer very properly

says, the best speeds are from 2,500 to 4,500 feet per minute. The explanation given here on page 20, first paragraph, is very interesting. I think that must have been a compound winder, if I know anything about it.

Anyhow, it goes to show how a useful thing and how a good thing sometimes can be abused, and I lay stress upon what the writer said in the closing remarks of his paper, that these driving arrangements well thought out and arranged for specific purposes are certain to prove efficient and economical. There is no question but that the transmission of power by ropes can be made more useful and can be used where today thousands of horsepower is being wasted.

Mr. Peck: I would like to make one or two comments on the very interesting remarks that Mr. Walker has made. I did not mean to imply, by speaking of the American system, that it was an American invention. I have spoken of it as the American system because it is generally known by that name. I know it has been in use in England, but I think the Englishmen, when they had a good thing, did not know it, and the Americans are entitled to the credit of bringing it out and into practical use.

I want to speak, too, of Mr. Walker's system of loose grooves in the separate rope system. I did not speak of this, although I am very familiar with it, for, as I say in the paper, it was not my purpose to speak particularly of the English system. There is no question but Mr. Walker's device in the separate rope system is the salvation of that system; it is a splendid thing, and no one should think of putting in a drive of that kind without using it.

Mr. Walker made some reference to the Miller patent for equalizing or making up the loss of contact where the driven sheave is comparatively small and the driver large; the idea being to put flatter or less sharp grooves in the driver, and sharp ones in the driven. I am very familiar with this system and I know of all the drives of the kind that are in use in this city. The difficulty is, that you gain nothing by making the grooves in the driver of comparatively wide angle; you simply diminish the power it will transmit. The only way to make the driven wheels of any more power is to sharpen the groove, but it is not desirable to put a 30 degree groove, for example, in the driven sheave to compensate for the loss of contact, as this distorts the rope too much.

In regard to splicing: the splice is not *necessarily* the weakest part, yet I think that I may safely say that in nine cases out of ten where a rope transmission has given out, it has been due to the failure of the splice. Not that the splice can not be properly made, but as a matter of fact, it often is not, because the splicer may be careless or not sufficiently skillful.

I was very glad to hear Mr. Walker's comments on the comparative durability of cotton and hemp or manila, as his experience coincides exactly with my own. He spoke about the par-

ticular rope which he ran in comparison with cotton as a high quality of manila rope laid up with graphite and tallow. I refer in my paper to a very similar rope, made up without the graphite, distinguished by a red thread running through it. That particular rope was tested in the machine shown in the lantern slide, and the manila rope with the red thread showed very marked superiority.

I might say in regard to tests made with that aggregation of sheaves, that in nearly every case the rope first gave out at the splice, although the splice was made as carefully as could possibly be made. They were comparative tests, not absolute tests of the durability. They were more to determine in an entirely unprejudiced way what was really the best rope.

In the particular drive to which Mr. Walker refers, where after a long period of wet weather the tension carriage was drawn up, that was entirely because the tension carriage track was too short. As I said in the paper, this should be sufficient to take up about one-fortieth of the length of the rope, and the tension carriage in question did not have that provision. The particular drive is shown on next to the last page in the paper. A second tension carriage was added in one of the other towers, and the drive gave no further trouble.

Regarding the dynamo drive that was run when the basement was flooded, I do not know whether that drive ran in water, but I know it ran for two or three days immediately after the flooding of the basement. (I have since learned that it actually ran in water.)

The particular drive to which I make reference on page 312, shown as figure 142, I have seen run when covered with 6 or 8 inches of snow, icicles and that sort of thing all over it. The view was taken when there was snow upon it, as you can see.

I think, perhaps, I was not quite clear in what I refer to as compound winding, and what is known as re-winding. The latter is where the rope in passing from driver to driven is wrapped one or more times around another sheave near the driver before being led around the driven, and similarly around another sheave near the drive before being led back to the driver. That is done to get additional adhesion; in other words, to get additional arc of contact on the sheaves. As I have said, it is not a desirable thing for the reason that it makes so many bends in the rope. Its particular advantage comes in where there is a drive three or four hundred feet between centers, for example, where perhaps two or three ropes would be sufficient to transmit the power, but where they would slip in the grooves. The additional adhesion necessary is given by wrapping around the re-winder sheaves.

In what is known as the compound wind, the ropes are wrapped in pairs, or two ropes treated exactly as if they were one rope.

I do not know that I am altogether prepared to take back what I said on speed of ropes. I will take my chances on a rope run-

ning ten thousand feet a minute, where a good-sized rope is used on sheaves of proper size, rather than on a rope running at slower speed and not properly designed. That is, I think if the sheaves were made proportionately large to make up for the excessive speed, rope could be run very successfully at ten thousand feet per minute.

Mr. Walker: I would like to refer to one or two things that I think of, and the first would be in reference to the shape of grooves. After finding that ropes would take a set and assume a certain position and not rotate, I determined to make a groove that was elliptical in form (this groove you will find illustrated in the Walker Manutacturing Co.'s catalogue), so as to assist the rope to rotate. Why we should make a flat surface at all at any angle for the rope to come in contact with I do not see or understand, although it was started in that way and the sides were made in different angles to suit people's notions and requirements. I mention this because I know of works that have made pulleys with different angles for the same size rope, but still they have used flat surfaces with a slight curve in the upper part of groove. After thinking this matter over thoroughly I decided to use an elliptical groove, and I have done so ever since. I think that an elliptical form helps the rope to rotate. Now it is possible to make an elliptical groove quite acute, another one obtuse, and you get a very great difference in the pulling power on the arcs, that is, per foot of contact. So that although our friend Miller has got a patent on this feature of different angles of grooves, yet if you want to make it, you can do so. I think there is considerable merit in the system, especially if applied to the elliptical groove. I have found a great deal of satisfaction in using that form, and it seems to me that it is a natural one and can be made just as easy as any other form, because you do not have to trouble with angles. I have established a form, and, by-the-way, this same party that makes the Lambeth ropes at New Bedford (he has an office in Boston, the works are in Bedford) asked me some time ago to make them a complete set of drawings for grooves for ropes half-inch to four inches in diameter. I undertook the work and he supplies the elliptical groove sections if anybody asks him what he would advise for use with his ropes, he was so much pleased with the form. The inch rope referred to in the test I think is too small. I am not favorable to small ropes and, therefore, I do not think it is a fair test, because I do not think it is possible to make as good a splice in an inch rope as it is in an inch and a half or two-inch rope. I give my reasons for whatever they are worth. I would not use a rope for any purpose over, say, 75 horse-power, less than an inch and a half diameter. The largest rope that I know of being used at present is the one at the power station here at Jefferson and Washington streets, three inches in diameter. When that diameter was suggested Mr. Yerkes asked my opinion as to whether three-inch

rope was practical, as all the records from Europe and all the evidence he could get pointed to nothing larger than two-inch rope. I told him it was practical on the kind of drive he wished to use, it being for slow running cable machinery. The rope gives good satisfaction, and as far as I know, it is the largest diameter rope in use.

In regard to ropes being exposed to the weather, if they are well filled and taken care of there is no reason why they should not stand it. It is not possible to protect leather as it is to protect a rope. You cannot get material to lay on the surface of a piece of leather the same as you can get it to soak into a rope made of cotton or manila; so I think there is good reason why you can run a rope in the snow and sleet when you could not possibly run a belt under the same circumstances.

The question of driving a rope at ten thousand ft. speed with large pulleys would be a very easy thing to accomplish, but that is not the idea. The difficulty at issue with me is whether it is possible for the material to stay together, to withstand the speed, and in this particular I would like to ask any member of the club what is the greatest velocity of rope he has ever known? Let us get at some facts if we can in this direction, because I do not think it is possible to run a rope at that speed. According to the tests made of speeds of rope, a rope will go to pieces at that speed. I have never seen, personally, a rope that ran satisfactorily over fifty-five hundred feet. The question that naturally comes in connection with excessive speeds is, how long will the rope last at such speeds? That is the way to get at the utility of the question; I do not question the possibility.

I had a great deal of trouble at the Walker Mfg. Co.'s foundry in rope drive of traveling cranes. The foundry atmosphere where the ropes ran seemed to dry them out and I could find no filling that would do them any good; the ropes were each about seven hundred feet long, and there were three ropes independently tensioned. I took out those ropes, changed the pulleys and put on a first-class leather belt; I think it is the longest belt running in America; it ran several years. This was an experiment and, gentlemen, you need not be afraid to run a long belt. The belt was of the ordinary weight double leather belt as used on dynamos. The belt is tensioned same as a rope would be, and with good success. The belt was not affected with the gases and the heat as the ropes were.

A Member: I would like to ask Mr. Peck in connection with the re-winder, whether a tightening sheave could not be used to give the additional arc of contact as is sometimes done with a belt?

Mr. Peck: That can be done; I have known it to be done, but this puts a quick reverse bend in the rope which is very objectionable. The re-winder leads the rope all in one direction. We often have to do things that we do not like and, as a matter of fact, those par-

ticular cross drives shown in Fig. 147 which have been criticised, have been running now successfully for something like four years. Of course, the bend is a necessary evil. In regard to what you say of the use of large rope, I quite agree with you; large ropes are far more reliable and durable. I do not want to advocate the small rope, but assuming you have a small drive of twenty to twenty-five horse-power and you cannot use a sheave larger than three or four feet, you must employ the smaller ropes.

Mr. Carter: You speak on page 317 of the power absorbed by the American system as being about four per cent. I want to ask whether that would be the same if the load were all thrown off of the line shaft. Take the friction test in an engine, we will say, we want to get at the horse-power, what would be a fair basis to figure on?

Mr. Peck: That is about 4 per cent of the power of transmission by rope.

Mr. Carter: When the engine is loaded, or when it is empty?

Mr. Peck: When it is loaded.

Mr. Bley: I would like to get at the idea when we should use small rope and when large rope. Now, as I understand Mr. Walker, we ought to run the large rope whenever we can. As I am informed, that is rather contrary to belting practice. I think the tendency is to use large diameter pulleys and thin belts as a preferable condition. Now why would not the same conditions hold in rope practice? In fact, does not what is known as the American system really work the same thing as compared with the English system? You take your single small rope and wrap it several times around, in preference to taking a large rope. Now I want to get at the question of when to use small rope and when to use large rope. That is one point, and another thing I would like to ask, why not cut the groove in the pulley so that the rope will bear on the whole under side after it has turned a length of time to be thoroughly imbedded to do its work? What is the objection to having the rope bearing on the bottom of the groove as well as on the side? In that connection I would like to point to a fact in the case of some bicycles. The ball bearings used to be made on a straight conical center, the ball rolled on a conical surface; the same manufacturers now make the internal piece of a concave ring form, so that the ball, instead of bearing on a straight line, bears on the arc of a circle, giving a greater bearing surface. Now why does not the same rule apply to a groove and a rope running through it?

Mr. Peck: In regard to the size of the rope, there is almost always some condition that determines approximately what size of sheave can be used. I never, if I can help it, use a sheave smaller than forty diameters of the rope. If I find I am limited forty inches in the size of the sheaves, I put on an inch rope; if I can get a sixty-inch sheave, I put on an inch and a half rope; or

in other words, use the largest rope and fewest number of wraps that the diameter of the sheave permits.

In regard to letting the rope touch on the bottom, if this is done you simply depend on the frictional adhesion of the surfaces. In the V shaped grooves, you get the additioual adhesion from the wedging of the ropes in the groove.

Mr. Bley: Do I understand that as you increase the diameter of the pulley, you increase the diameter of the rope, is that your practice?

Mr. Peck: The mimimum diameter of the sheaves should be forty times the diameter of the rope. In other words, an inch rope should not be run on less than forty-inch sheaves.

Mr. Bley: It is run on smaller sheaves in practice?

Mr. Peck: Yes, it is done, but it is to be avoided wherever possible. Where the size of the sheaves admit it, I should use as big ropes as possible. Nobody likes better than I to use two-inch ropes where practicable.

Mr. Bley: Is not the wear and tear on the large rope; on the same pulley more in proportion than on the smaller rope?

Mr. Peck: No, within certain limits. You take a new manila rope, there are a certain number of strands that are bound to suffer. They cut a very small figure on the large rope; on a small rope they would cut more figure.

Mr. Bley: Theoretically, when you bend a rope around a pulley you are stretching the outside strands and compressing the inner strands. Now if that is true, why does not increasing the rope increase the trouble?

Mr. Peck: That would be so if you did not increase the diameter of the sheave properly.

Mr. Bley: I mean on the same size sheave.

Mr. Peck: It would.

Mr. Bley: That would argue, then, that you ought to use the smaller sized rope.

Mr. Peck: Yes, I see your point. Well, there are other objections to the small sized rope. As I say, when you do break the strands you destroy a very much larger proportion of your rope than when it is larger.

Mr. Bley: Then I understand that you will take one-fortieth of the diameter of the pulley as the maximum of the diameter of the rope?

Mr. Peck: Yes. Mr. Walker made some reference to the use of round bottomed grooves and elliptical shaped grooves for idlers. Where the rope makes half a turn, it is not very material which you use. Where the rope simply lies on the idlers, the form of groove does make a great deal of difference. Where a rope is run a little over round bottom grooved idlers you find it polished by the slipping of the rope; that indicates that when the rope starts up it does not at once overcome the inertia of

the idler, but slides over it. With the V groove the rope takes hold sufficiently to bring it at once up to speed.

Mr. Walker: I think, to make this matter a little more clear, I will say, it will be understood that a two-inch rope will work just as easy on an 80-inch pulley as a one-inch rope on a 40-inch pulley, just in that proportion, diameters and circumference, all have the same relation, and that being understood, if your work will admit you to use an 80-inch pulley, then you will use a two-inch rope; but if your work will not permit you to use anything larger than a 40-inch pulley, you will be compelled to use a one-inch rope; there is no choice; so that the designer of the rope transmission must be careful to always get the pulleys as large as consistent with conditions and economy, etc., and then to make his rope suit the pulley. If he keeps the pulley large, he certainly can get a large rope on it. That is the only thing that you are bound to take care of. There is no place where you can fix your mind and say, we will stop using this size rope here and use that one there; it is all a matter of circumstances and conditions that the engineer must take care of.

With regard to the bottoming of ropes on the grooves, they would answer for idlers but not for drivers, as ropes will get less in diameter from two causes. First, from friction in driving; second, from tension; they never get larger, they are always getting smaller. Those two things cause your ropes to reduce, so that shortly you will have at least a two-inch rope down to an inch and three-quarters and then an inch and a half. You can see new ropes at Jefferson and Washington street power station put in at three inches and you will see the old ropes on the drum about two and a half. So that you see you have to assume what would be the smallest size of your rope before it would break or be thrown out, and then you must have the bottom of the groove sufficiently small so that it can do its work to the last. There are no satisfactory rope drives where the rope touches the bottom.

Member: There are one or two questions I want to ask. A piece of work came under my supervision with which the difficulty arose as to whether we should construct a straight drive or have an idler, and I was not able to find data from which to obviate the loss through an idler.

Mr. Peck: Do you mean that this was a rope without a tension carriage?

Member: No.

Mr. Peck: The rope does not depend upon its weight between the sheaves for adhesion where there is a tension carriage, and the idler makes no difference in the transmitting power. Where there is no tension carriage an idler between the two sheaves might make a very serious difference.

A Member: In this case the driver was some eighty feet from the driven pulley from the sheave.

Mr. Peck: An idler would not be necessary.

Member: The point was to keep the ropes as close to the wall as possible and that would necessitate their running over the idler, so they would not take up room required for other purposes.

Mr. Peck: The idler should make no difference in transmitting power.

Member: Another question. I have observed in the floating pulley-box that it made considerable difference in which you threaded the rope, as to whether those pulleys would attempt to twist and cause considerable friction, sometimes stop the machinery in hoisting material. Has there been any observation in this line, as to the tendency to rotate the sheaves?

Mr. Peck: I do not know of any observations made. Rope always has to be wound on the sheaves spirally. I have seen drives with the ropes run on both ways, running side by side, but have never seen that it made any difference in the operation or durability of the drive.

Member: With a tight twisted rope it makes quite a difference.

Mr. Peck: Tight twisted rope should not be used for transmissions, tho' all right for hoisting ropes, where is used the tightest rope that is made.

Member: Speaking of the rope running more quietly than belt, why is it?

Mr. Peck: Well, there is the suction of the air under a belt that makes a great deal of noise, the slapping of the belt on the pulley and the tendency to create a vacuum under the belt as it comes off.

Member: My attention was called a few days ago to a plant where they had been grooving the pulleys. The idea was that the belt pulled the air in on top of the pulley and partly raised it, making a slip and it grooved the pulley and allowed the air to escape. This was an electric plant, and by putting in the small grooves they were enabled to loosen the tension.

Mr. Walker: I was going to suggest that possibly the writer might follow this subject up advantageously and with benefit to the Club. There is a very important thing in these rope drives, a similar question comes up in cable work, to know what we are doing with each of the wraps in the endless system. It is a very important question and worthy of a separate paper to get that matter properly worked out and brought intelligently before this Club. I merely make the suggestion, possibly some of our members will take the matter up.

I know some years ago I had to do with the cable roads in New York, and I met Col. Payne, of Brooklyn Bridge fame. He had to do with the roadway and afterwards with the cable equipment of the Bridge. It was one of his hobbies to figure out and talk of the different strains on a cable drum. Of course, you are all aware the initial strain coming on the drum varies considerably. Take a constant load even and take that down to the tension carriage, through the various wraps and conditions, it is a

very nice proposition. Each tangent varies in load, and then comes the next question, in the length of the successive wraps whether the cable is shortening as the tension is getting less from one tangent to the other in a straight line, or whether it differs on each semi-circle as it passes over same. True it is that initial strain is one thing and the strain on tension carriage is another. Whether any practical method of testing the horse-power passing through each individual wrap can be devised is something that I would like to learn about. I am somewhat interested in the same question in cable railroads, because it affects the differential drum that is known under my name and has been used so often throughout the United States. It is very similar in rope drives, and if it could be arrived at it would be a desirable thing for the designer in continuous rope driving appliances.

Written discussion by SPENCER MILLER of New York.

I have before me a copy of Mr. Peck's paper on "Rope Transmission," and the discussion thereupon.

Mr. Walker touched lightly on what he was pleased to call the "Miller System" of equalizing the strains in the various strands in a rope drive. I want to explain the matter more fully.

Some ten years ago, I had occasion to study the subject of rope driving and was much puzzled at one installed with wooden sheaves. This particular transmission had a driver about three times the diameter of the driven, and both wheels wore badly in the grooves. The first groove wore down fully an inch, the second ¾", the third ½" and so on.

I also noticed that another rope drive in thesame building, having the sheaves of the same diameter that the grooves wore alike.

Hence the conclusion that the unequal wear was attributable to the unequal arc of contact occurring in the drive with pulleys of different diameter.

The substitution of iron sheaves for wooden ones prevents this object lesson from being brought to every one, but the unequal strains on the various strands are there just as before, and can be seen if one will notice the difference in the sag of the various ropes.

Taking this matter in its simplest aspect, let us consider a belt transmission, for example, a dynamo drive; it is the small pulley that needs covering with leather to increase the holding power of the belt, and in a rope drive it is the small pulley that needs attention, the simplest plan of increasing the holding power of the rope being to diminish the angle of the groove. If we fix a limit of sharpening the angle of groove to 35, 40 or 45 degrees, then that becomes the angle for the small pulley. The rope cannot transmit more power than the small pulley will

receive, hence there will be no loss of effect by making the angle of the large pulley wider.

The angle of the large pulley will be reduced so that the frictional hold on both pulleys is alike. This is done by making the product of the arc of contact by the co-efficient of friction of each pulley the same. With this done we have made three apparent savings. The most important saving requires considerable demonstration, and a diagram that I cannot get ready in time for this discussion, but what is perfectly evident to every one is, that there is—

1st. A saving of cost of a large pulley with its wide angle groove. This saving is only apparent, however, in pulleys of very large diameter.

2nd. Whatever loss of power is occasioned by pulling out the rope from a sharp angular groove is reduced by using the wider angle on the large pulley.

3rd. The life of the rope will be prolonged by virtue of the wider angle.

If in a power transmission all the ropes can be depended on to take their equal share of the work, then a smaller rope may be selected or else less number of wraps of the same rope, making a saving again in the cost of the sheaves and the life of the rope.

For a theoretical discussion of this very important matter, Professor Flather's book on "Rope Driving," pages 159 to 176.

The following table based on a co-efficient of friction of .12 may be used to arrive at the proper angles for equal adhesions.

Arc of contact on small pulley / Arc of contact on large pulley =	0.9	0.8	0.75	0.7	0.65	0.6
Angle of groove in large pulley when groove in small pulley—35°	40°	44°	47°	51°	55°	60°
" " —40°	45°	50°	54°	58°	64°	70°
" " 45°	50°	55°	60°	66°	72°	80°

and is taken from "Rope Driving."

As a practical proof of the value of the variable grooves, I would refer to a rope drive designed by me some nine years ago, and installed in the planing mill of J. K. Russell, on Fulton St., Chicago, where they have been transmitting 250 H. P. with 12 strands to ⅞" rope, which lasted six years. According to the present practice 1¼" rope would be employed. A 14' driver is grooved to an angle of 60 degrees and the 6' driven pulley to an angle of 45 degrees. The rope may be seen to be pulling alike and each doing its own share of the work.

X.

CONCRETE WATER-POWER DAM AT ROCK ISLAND ARSENAL, ILLS

By Lieut. Odus C. Horney, U. S. Ordnance.

Read June 2, 1897.

A wall was constructed in pursuance of plans for the development ot the water-power at Rock Island, and was to replace an old stone wall that was considered unsafe.

The main channel of the river, which at this point runs from east to west, is on the north side of the Island, while the power is taken from the south side, the total fall from the head of the wing dam to the lower end of the Island being about eight feet.

In the old wall the water wheel openings were arranged in a number of groups distributed irregularly along its entire length of 2,238 feet.

By concentrating the openings, a wall about 400 feet in length was made to replace the longer one.

In plan the new wall is L shaped, the two wings being 192 and 208 feet long, respectively, with a heavy triangular pier at the angle.

The wheel openings are twenty-five in number, twelve in one wing and thirteen in the other.

Although the head of water is only about eight feet, the great variation in the stage of water in the Mississippi River rendered it necessary to put the top of the wall at an elevation of 25 feet above low water mark.

As the bottom of the wheel pits is 5 feet 6 inches below low water mark, the total height of the wall is therefore 30 feet 6 inches. It contains approximately thirty-five hundred cubic yards of concrete.

The gate openings are eight feet square with the top in the form of a segmental arch having a rise of eight inches.

The gates are made of cast iron in five pieces, which work up and down between cast iron slides bolted to the wall.

The wall is 6 feet 6 inches thick at the base and 3 feet 6 inches thick at the top, with counterforts that extend back 16 feet, and form the sides of the penstocks.

The countertorts up to a height of 6 feet are 4 feet thick, and above that 3 feet thick, thus making an offset of 6 inches on each side upon which the flume floors will rest.

Fig. 151.

The site of the wall being under water, it was necessary to build coffer dams around it.

The one above the wall was 10 feet thick and 16 feet high (it was not filled quite to the top of the planking), and 500 feet long.

It was constructed with three stringers 6″×8″ tied together with 1-inch iron rods, spaced 7½ feet apart. The planking was of common 2″×10″ pine, beveled at the bottom and driven to the rock. The filling, which was a heavy silt, was dredged from the water power pool and carried to the coffer on flat boats.

The coffer dam below the wall was only 6 feet thick and 12 feet high, with two stringers 4″×6″ tied together with ¾-inch rods 7½ feet apart. In pumping out the area enclosed by the coffers a 10″ centrifugal pump was used, the power being a 20 h. p. electric motor.

It was necessary to keep this pump running continuously during the progress of the work, as the seams in the rock permitted constant leakage under the coffers, and there were, besides, several springs within the area enclosed.

Before the new wall could be erected, a stone dyke 60 feet wide at the bottom, 15 feet wide at the top, and 24 feet high with

Fig. 152.

a masonry core had to be removed, and a similar dyke constructed at a short distance away.

This stone dyke was removed by loading into dump boxes placed on small cars, which were hauled up an incline to the height of the new dyke by a hoisting engine.

Four cars were taken out at once (each containing about ¾ of a cubic yard), the line being attached to the rear end of the fourth car which pushed the other three up the incline and around a curve in the track, when they were carried by gravity to the dump, and afterwards to the starting point, the track being laid in a continuous circuit.

In erecting the wall, the foundations up to the level with the flume floor were first placed and allowed to harden for several days before the upper wall was begun. A level surface was thus secured upon which to erect the large moulds.

These moulds were built of timbers 8″×10″×24′, placed vertically and tied together with ¾″ iron rods, which were left in the wall when the moulds were taken down, the projecting ends being afterwards cut off.

The planking was 2″×12″×16′ dressed to uniform thickness, and lightly nailed to the uprights at the ends.

In beginning the work, it was thought advisable to plank up only a few feet of the mould at a time, building it up as the concrete was laid, but a brief experience showed the impossibility of doing this economically, and the moulds were thereafter completed before any concrete was placed in them.

Three-inch planking was first tried, but was not satisfactory, as it would warp (when the inside became damp during the placing of the wet concrete), and it was difficult to draw it back into shape. The two-inch planking (dressed to about 1¾″) gave excellent satisfaction, as the tendency to warp was easily overcome, the tamping of the concrete readily bringing it to its place.

The lighter planking is also cheaper and easier to handle, and narrower pieces (say 8″ wide) would probably be better than that used, which was 12″ wide, as the loss from falling and breaking and splitting while taking down the moulds would be less. Lighter vertical timbers could also be used, but this would necessitate a greater number of rods, say one every three feet. Whether or not this would be an advantage would depend upon circumstances. In this case, it probably would have been, as the frequent handling of such heavy timbers as those used consumed considerable time.

The moulds were 16 feet long, a counterfort being at the middle of each one, and one mould containing about 95 cubic yards was filled each day.

The center of each section being taken at the middle of a counterfort, the vertical joint between adjacent sections came over the middle of the gate openings. These vertical joints were made so that the two sections were locked together.

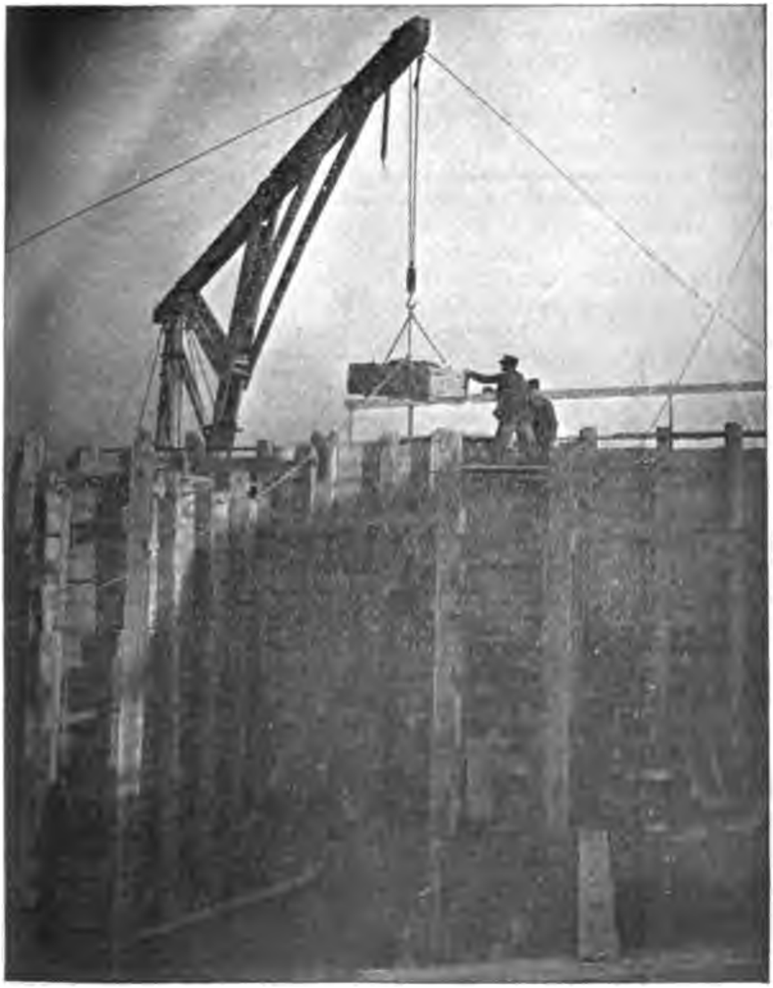

Fig. 153.

As each mould was filled from bottom to top in a single day, there are no horizontal joints in the wall, except at the top of the foundations. As a precaution against sliding at this point, 3" planks were imbedded in the foundation with their top surface flush with the upper surface of the concrete; when these planks were removed, they left a series of depressions in the top of the foundations, into which the concrete of the wall was rammed.

The object of building the wall in this manner, that is, in short sections, with none but vertical joints, was to locate all cracks caused by shrinkage in setting, and by contraction from cold at predetermined points, and to secure a number of small cracks instead of a few large ones. This mode of construction was adopted after observation of another water power dam at Rock Island Arsenal, which is built of sandstone. During very cold weather a number of cracks are developed in this sandstone wall, due to the contraction of the masonry.

In a total length of 650 feet can be counted eight vertical cracks, several of which were more than an eighth of an inch wide, the total contraction being about one inch.

These cracks occurred at irregular intervals and ran in zigzag lines from the top of the wall downward. In some cases they coincided with joints between the stones, but in others they ran through the stones, and in one case a large stone two feet thick was cracked right through the middle from top to bottom.

Had this unavoidable contraction caused the formation of 41 cracks, corresponding to the 41 gate openings, they would each have been only one-fortieth of an inch wide.

No setting cracks in the concrete wall were noticed, but as cold weather came on the joints opened very slightly, as was expected.

No facing of sand and cement was used, the only attempts to make the surface smooth being to have the concrete thrown with shovels hard against the sides of the mould.

The materials used in the concrete were Empire Portland cement, sharp, clean river sand and crushed limestone, unscreened.

The stone used for crushing had been exposed to the weather for years, was well seasoned and very hard. Freshly quarried stone was used a little, but it was found that much less of it could be crowded through the crusher in a day.

About 50 per cent. of this crushed stone would pass through a one-inch sieve, about 17 per cent. would pass a No. 3 sieve, and about 9 per cent. would pass a No. 8 sieve.

These materials were mixed in the following proportions: 1 barrel of cement, 4 barrels of sand and 9 barrels of broken stone, each barrel of cement giving almost exactly a cubic yard of concrete when tamped to place.

The concrete was mixed in a Cockburn-Barrow mixer with screw feed, and carried in dump boxes on cars to the point where

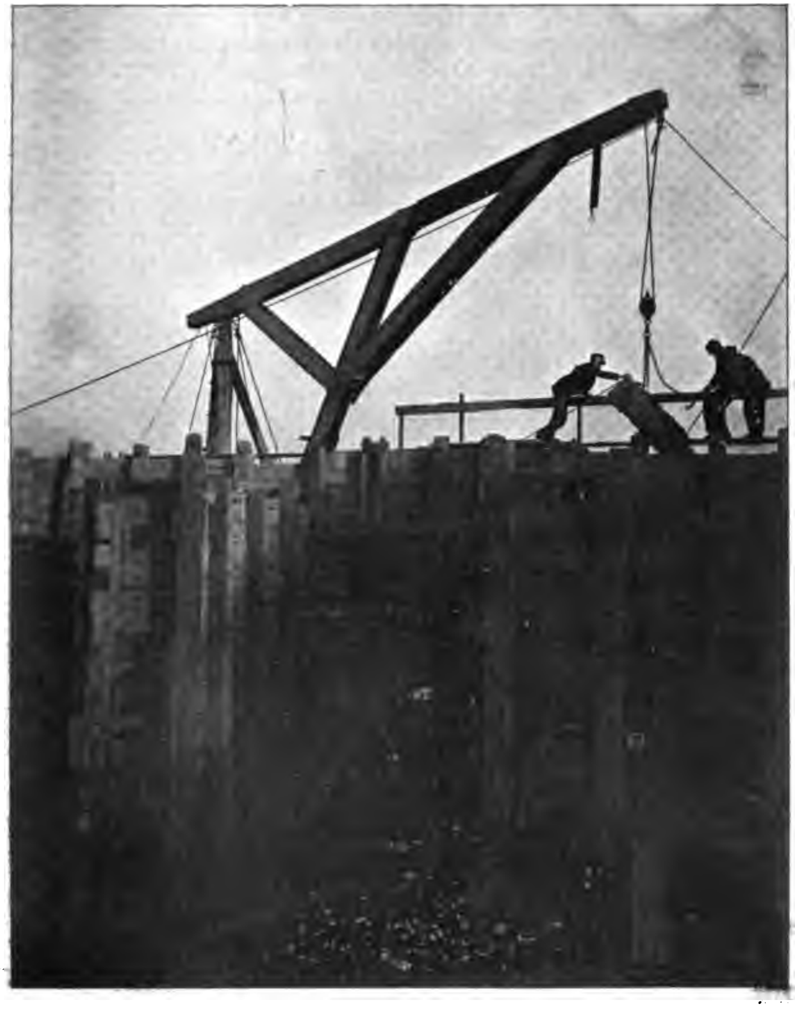

Fig. 154.

it was to be placed. It was then elevated to the top of the mould by means of a crane derrick and a steam engine.

The dump boxes used were made of a 2-inch pine planking and were 2 feet wide, 5 feet 4 inches long and 14 inches deep.

They were usually loaded with about ¼ of a cubic yard of concrete.

The derrick was on wheels and was moved along a track as the work progressed.

As the concrete was dumped into the moulds it was spread by a gang of men working with shovels, who were required to throw the concrete hard against the sides of the moulds, the shovelers being followed by a gang of men who rammed it to place. The rammers used were made of cast iron with wrought iron handles, and weighed about 30 pounds each.

The concrete, which was mixed as wet as it could be made without causing the mass to quake when tamped, was placed in thin layers (not over six inches) and the ramming was very thorough.

The cost of the labor of mixing, and placing the concrete, was as follows:

1.	Cement	$9,500
2.	Sand	400
3.	Storing and hauling cement by team and boat to the points of consumption	460
4.	Taking sand from barge to mixer	96
5.	Crushing stone	1,450
6.	Mixing concrete	4,825
7.	Placing concrete	1,670
8.	Erection and taking down of moulds	2,450
9.	Lumber for moulds	600
	Making a total of	$21,451

which is approximately $6.13 per cubic yard of concrete laid. In this connection it should be noted that the wages paid common laborers was $1.50 for an eight-hour day.

Less cement was used in this wall than is ordinarily the case in important works.

Two reasons for this may be given.

First: The strength of the cement used was very high, and the terms of the contract were such that it is believed very little inferior cement could have been passed, even had the contractors been inclined to attempt such a thing.

Second: All work was done by day labor directly under the supervision of the officer in charge of the work, and there was no temptation to do inferior work.

The specifications for cement required a tensile strength (at the end of seven days) in the neat cement of 450 pounds per square inch, and in a three to one mixture of 140 pounds per square inch.

Although all the acceptance tests of all the cement received were entirely satisfactory, another series of tests was carried on during the progress of the work which was considered of more value and importance.

It is thought that the results of these tests furnish ample grounds for believing that the proportions of stone, sand, and cement were well chosen, and that a thoroughly good construction was obtained at a very low cost.

Fig. 155.

These tests were as follows:

Briquettes for both tension and compression were made in the field out of the mortar from the concrete. The concrete was taken just as it came from the mixer, the stone picked out by hand, and the mortar used for the briquettes.

The briquettes for tensile tests were of the standard dimensions, those for crushing were 2"x2"x4" and were intended to be crushed on end.

Most of them *were* so crushed, but in order to see how much stronger they were on the side, a few were crushed in that position. Strange to say, but comparatively little difference in the strength was noted, as may be seen from subjoined tables.

The average crushing strength per square inch at the end of 30 days, when broken on end, was 1,242 pounds, and when broken on the side was 1,671 pounds.

At the end of 90 days the average crushing strength per square inch was 1,469 pounds when broken on the end, and 1,937 pounds when broken on the side.

At the end of 120 days the average crushing strength per square inch was 1,675 pounds when broken on end, and 2,249 pounds when broken on the side.

In addition to these small briquettes from the mortar there were also a number of concrete blocks made for crushing.

The clamps at present on the testing machine are adapted to crushing specimens whose horizontal dimensions are less than 4×6 inches. As an alteration in these clamps would have involved considerable expense, all the concrete blocks were made 3¾ inches wide, and 5¾ inches long, and 8 inches high.

Another set of specimens 3¾"×5¾"×27" was made for breaking by transverse stress.

When it was noticed how little difference there was in the crushing strength per square inch of the small specimens when broken on end and when broken on the side, it was decided to extend this test to the larger specimens. Three of these long blocks were sawed in two, making from each two blocks for crushing, 8 inches and 19 inches high respectively.

The crushing of these gave results even more remarkable than those obtained in the case of the small ones.

The crushing strength per square inch of the three blocks 8 inches high was 1,486, 1,396, and 1,309 pounds, respectively, while the corresponding pieces which were 19 inches high gave 1,391, 1,577, and 1,345 pounds, respectively, which was higher on an average than in the case of the three 8-inch blocks.

Particular importance is attached to these field tests, as it is thought that they show more nearly what was the actual strength of the material as it went into the wall than could any laboratory tests, however carefully made, and the results obtained indicate very clearly the value good concrete would have for use in columns or high thin walls.

Fig. 156.

Tensile tests of mortar used in the construction of water power dam at Rock Island Arsenal, Ill. Concrete from which this mortar was taken was composed of 1 part Empire Portland cement, 4 parts sand and 9 parts crushed limestone.

No. of Specimen.	Dimensions.	Area to which stress was applied.	Duration of test.	Breaking Stress. Total.	Breaking Stress. Per sq. in.	Remarks.
1	Standard tensile briquettes	....	7 days	160		Made from mortar from machine mixed concrete Nov. 16th. Weather dry and moderate. Briquettes remained in open air 48 hours and then placed in water.
2		....	"	164		
3		....	"	120		
4		....	"	150		
5	"	....	"	145		
1	"	....	"	146		Made from mortar from machine mixed concrete Dec. 9th. Weather freezing. Briquettes were removed to a warm room to set, remained there 24 hours, then removed to testing room and placed in water.
2	"	....	"	145		
3	"	....	"	152		
4	"	....	"	149		
5	"	....	"	144		
1	"	....	30 days	157		Made from mortar from machine mixed concrete Nov. 24th. Weather warm and damp. Briquettes left outside. The 26th it rained all day and in the evening changed to freezing. Briquettes remained in the freezing weather until the 28th. Immersed in water the 30th.
2	"	....	"	157		
3	"	....	"	200		
4	"	....	"	162		
5	"	....	"	196		
1	"	....	60 days	207		Made from mortar from machine mixed concrete Dec. 9th. Weather freezing. Briquettes were removed to a warm room to set, remained there 24 hours, then removed to testing room and immersed in water.
2	"	....	"	206		
3	"	....	"	250		
4	"	....	"	222		
5	"	....	"	209		
6	"	....	"	220		
7	"	....	"	203		
8	"	....	"	209		
9	"	....	"	204		
1	"	....	120 days	337		Made from mortar from machine mixed concrete Nov. 16th. Weather dry and moderate. Briquettes remained in open air 48 hours and then placed in water.
2	"	....	"	357		
3	"	....	"	378		
4	"	....	"	370		
5	"	....	"	280		
1	"	....	"	290		Made from mortar from machine mixed concrete Nov. 24th. Weather warm and damp. Briquettes left outside. The 26th it rained all day and in the evening changed to freezing. Briquettes remained in the freezing weather until the 28th. Immersed in water the 30th.
2	"	....	"	294		
3	"	....	"	294		
4	"	....	"	293		
5	"	....	"	298		

Crushing tests of mortar from concrete used in the construction of water power dam, Rock Island Arsenal, Ill. The concrete from which this mortar was taken was composed of 1 part Empire Portland cement, 4 parts sand and 9 parts crushed limestone.

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No. of Speci- men.	Dimen- sions.	Area to which stress was ap- plied.	Dura- tion of test.	Breaking Stress. To- tal.	Breaking Stress. Per sq.in.	Remarks.
1	2x2x4″	2 x 2″	30 days	3785	946¼	Made from mortar taken from machine mixed concrete Nov. 25th. Weather damp and moderate. Specimens were left in open air. On the 26th it rained all day and the weather changed to freezing in the evening. Specimens remained out in freezing weather until the 28th and then removed to testing room. Immersed in water on 30th.
2	"	"	"	3570	892½	
3	"	"	"	3850	962½	
4	"	"	"	4425	1106¼	
5	"	"	"	4830	1207½	
1	"	2 x 4″	"	9375	1171⅞	Made from mortar taken from machine mixed concrete Dec. 7th. Weather freezing. Warm water used in mixing concrete. Specimens removed to warm room to set. Taken from moulds on the 8th, immersed in water on the 9th.
2	"	"	"	11550	1443 2-8	
3	"	"	"	11200	1400	
4	"	2 x 2″	"	5050	1262½	
5	"	"	"	4900	1222	
1	"	"	90 days	4900	1222	Made from mortar taken from machine mixed concrete Dec. 8th. Weather freezing. Specimens were placed in warm room to set. They were removed from moulds Dec. 9th and on the 10th immersed in water.
2	"	"	"	7650	1912½	
3	"	"	"	5100	1275	
4	"	2 x 4″	"	15200	1900	
5	"	"	"	15800	1975	
1	"	2 x 2″	120 days	5850	1462½	Made from mortar taken from machine mixed concrete Nov. 16th. Weather dry and moderate. Specimens remained in open air 48 hours and then placed in water.
2	"	"	"	7100	1775	
3	"	"	"	7150	1787½	
4	"	2 x 4″	"	18200	2273⅔	
5	"	"	"	17800	2225	

Crushing tests of concrete used in construction of water power dam at Rock Island Arsenal, Ill. Concrete composed of 1 part Empire Portland cement, 4 parts sand and 9 parts crushed limestone.

No. of Speci- men.	Dimen- sions.	Area to which stress was ap- plied.	Dura- tion of test.	Breaking Stress. To- tal.	Breaking Stress. Per sq.in.	Remarks.
1	3¾x5¾ x8″	3¾ x 5¾″	30 days	30735	1407	Made from machine mixed concrete Nov. 24th. Weather warm and damp. Specimens left in open air to set. On 26th it rained all day and in evening weather changed to freezing. Specimens remained in freezing weather until 28th, when they were removed to testing room. Not immersed in water.
2	"	"	"	24890	1154	
3	"	"	"	25200	1169	
4	"	"	"	25660	1185	
5	"	"	"	24050	1115	
6	"	"	"	21605	1002	
1	"	"	"	24870	1153	Made from hand mixed concrete Dec. 12th. Weather moderate. Specimens left in open air until 14th, when they were removed to testing room. Not immersed in water.
2	"	"	"	23500	1089	
3	"	"	"	31450	1435	
4	"	"	"	24450	1134	
5	"	"	"	23350	1083	

1	3¾x5¾ x8"	3¾x 5¾"	60 days	26300	1219	Made from machine mixed concrete Nov. 13th. Weather warm. Specimens left in open air until they were set. They were removed to testing room Nov. 15th and immersed in water, remaining in water until crushed.
2	"	"	"	27400	1270	
3	"	"	"	23050	1068	
4	"	"	"	28650	1328	
5	"	"	"	25750	1194	
1	"	"	90 days	25800	1197	Made from machine mixed concrete Dec. 7th. Weather freezing. Warm water used in mixing concrete. After specimens were made they were removed to warm room to set. Not immersed in water.
2	"	"	"	27000	1252	
3	"	"	"	26300	1219	
4	"	"	"	25700	1192	
1	"	"	120 days	32050	1486	
2	"	"	"	30100	1396	Made from machine mixed concrete. Weather dry and moderate. Left out of doors 48 hours and then removed to testing room. Not immersed in water.
3	"	"	"	28200	1309	
1	(a) 3¾x 5¾x19"	"	"	30000	1391	
2	"	"	"	34000	1577	
3	"	"	"	29100	1345	

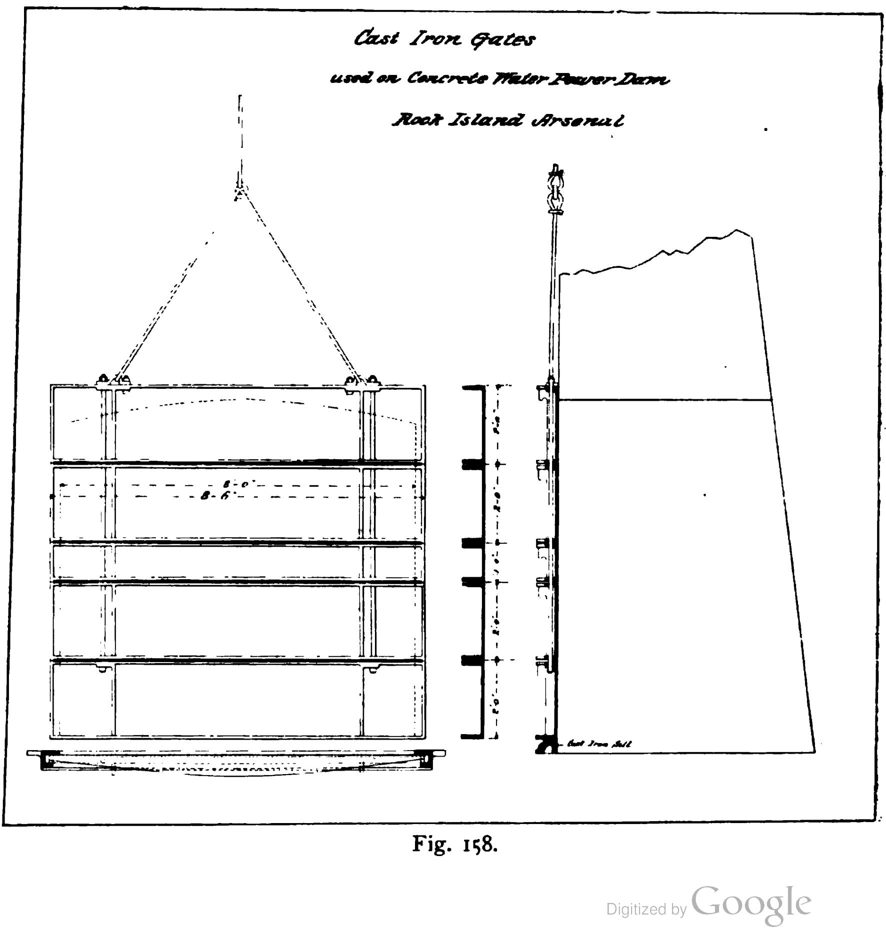

Fig. 158.

DISCUSSION.

Mr. Morison: There is one question that I would like to ask and that is, whether any careful observations were made as to the expansion due to temperature of the concrete that was made there. With a delicate apparatus one of these nineteen inch blocks could have been tested in that way.

Lieut. Horney: They were not tested.

Mr. Morison: This is a subject that I think would be of interest if we could have more information on it. I think it would be interesting to have a concrete beam twenty feet long made and kept in some room with a delicate apparatus by which the changes of length could be measured. I believe that there is an important future for a combination of concrete with a steel skeleton; I do not know whether the X Rays can be made to reveal the character of a skeleton of this kind, but I believe that the future of that class of construction is a very great one. While it is generally conceded that the difference of the rate of expansion of steel and concrete when kept at the same absolute temperature is not enough to have any appreciable effect, I think that observations of that kind would be very valuable.

President Johnston: Mr. Harrison is present with us this evening; perhaps he can tell us something about the expansion and contraction due to temperature.

Mr. Harrison: I have not made measurements to determine the actual expansion and contraction of concrete walls, due to changes of temperature, but I know that such expansion and contraction takes place, though to what extent for any given change in temperature I have no data.

President Johnston: Have you observed in any general way in the concrete walls on sections 14 and 15 of the drainage canal how far apart the expansion cracks are? I believe they show very plainly.

Mr. Harrison: The concrete wall on sections 14 and 15 is continuous for about nine thousand feet, and during last summer when the wall was built there were no cracks noticed. In the fall when the weather began to get colder, quite a number of cracks developed, and during the winter there were a great many; the distance apart varied. In some cases they would be almost regularly spaced about every twenty feet; in the other instances they would be two or three hundred feet apart; some are larger than the ones that Lieut. Horney speaks of; I have seen them as much as a quarter of an inch, and extend from the top of the wall to the bottom, and almost at right axes to the angles to the wall.

President Johnston: These walls, I believe, are six feet wide on top?

Mr. Harrison: The cross section of the wall is six feet on the top, and that width is continued down to a depth of eight feet from the top of the wall; then the wall steps off, one foot tread

and two foot rise, and the general cross section of the wall being the base two-thirds the height of the wall.

I think, however, that the Society should feel very much indebted to Lieut. Horney for the very able paper he has presented on the subject of concrete, because there are so many different kinds of concrete made that I think it is a good thing for engineers to learn what is the best concrete and which is the best method of making it. I believe concrete construction is a better construction than many people have considered it to be in the past.

Prof. Feldman: I would like to ask Lieut. Horney especially about the ramming—did you ram the test pieces after making the briquettes?

Lieut. Horney: Yes, except in the case of the small ones; those 2 by 2 by 4 made of mortar freed of stones were pressed in with the thumbs. Our concrete specimens 3¾x5¼x8 inches were rammed by a little rammer weighing perhaps as much as two or three pounds, but it was impossible to ram it as thoroughly as the mass for the wall was rammed, so that the error in the strength of test piece was in the right direction.

Prof. Feldman: You did not ram the small ones for tension?

Lieut. Horney: No, all small briquettes were pressed in as ordinary briquettes are made in the laboratory, by thumb pressure.

A Member: I would like to ask what was the distance in curb?

Lieut. Horney: The distance would be 13 feet, 16 from center to center, openings are 8 feet square.

A Member: What sized wheel are you going to use?

Lieut. Horney: I don't know; the wheels will not be placed by government; they will be used by the Moline Water Power Company; the water power is owned by the government, subject to the condition that the Moline Water Power Company shall have a portion of the developed power and they furnish their own wheels, and it was their old wall that was being replaced; they of course will use the new one.

Mr. Morison: In regard to the expansion and contraction of concrete, the method of measuring long walls is certainly very interesting, but I hardly feel as if it would give exactly the results we ought to have. The difficulty of getting results from it is to ascertain the real temperature of the walls; you can ascertain the atmospheric temperature, you may be able to ascertain the surface temperature, but concrete is not like metals, it is not a rapid conductor of heat, and there may be a great difference in the temperature of the wall at the surface and of the wall two feet from the surface; it is for that reason that I feel as if it were time for somebody to make tests of isolated blocks of concrete which could be surrounded by the atmosphere on all sides

and remain so a sufficient length of time to have something like a uniform temperature throughout.

I fully believe that we are now only at the beginning of the use of concrete construction, and that if the results we hope for can be obtained with concrete structures, with metal structures inside, the time will come when this will be the one method of building. A concrete mass with a metal skeleton, a concrete of such composition that the concrete absolutely protects the metal from corrosion, which is something that we may expect today, and a concrete which will be as good as the majority of natural stones, which we ought sooner or later to be able to make, is the ideal building material for buildings like the one we are in. It would be immensely better than a steel skeleton covered by a thin layer of terra cotta with the oxidizing atmosphere circulating all around within. I believe the time will come when an artificial stone made in this way will be more used than anything else.

Prof. Feldman: I want to add to Mr. Harrison's remark about the different temperature. There is a method used by a professor of McLean's University, a method of testing temperatures at different depths, and he gets his thermometers in place by different ways and he can get the temperature at any depth.

What I wanted to ask was, whether the percentage of water was taken, and if so, what was the percentage?

Lieut. Horney: No, the mixer supplies the water after the ingredients have been mixed dry. It comes in regulated by a stop cock and, as I said before, it is a matter of experiment to get the concrete of such a consistency that it would not quake when tamped, and I attempted at all times to get it as wet as I could without causing the mass to quake when tamped.

Prof. Feldman: You did not take the percentage of water of the set.

Lieut. Horney: There was no definite way to determine that. It would have been very difficult to get the concrete too wet in the high moulds that I used, due to the fact that the water would seep out over the boards as each layer was tamped. I made it just wet enough to avoid quaking.

Prof. Feldman: You mix it before you put it in the mould.

Lieut. Horney: Oh, yes. We spoiled several batches when we began, but after a time the man who watched the stop cock became quite expert in telling when it was just right; it was only a matter of a few drops in a large batch whether it was too dry or too wet, I found. There was one thing happened that might be interesting. The first mould that we filled was wetter than I intended to make it, and that was also the mould which we tried to fill in before the boards were all put on. The boxes containing the concrete would jostle against the sides of the mould and knock it out of shape. I had to cut off the front of that 16 foot block of concrete and a portion of the next one adjacent to it which was put in dryer; I found, much to my surprise, that the

wet one was much the harder of the two when cut across the face.

Prof. Feldman: Could you not get more concrete in a cubic foot when it is wet than you could when it is dry?

Lieut. Horney: I do not know from practical experience; I have heard of experiments, but I believe there is something else in connection with that that would have to be considered. You might avoid certain faults by adding water, at the same time you would have the mass full of very small pits, or bubble holes, like blow holes in castings; you notice that in very wet concrete.

Mr. Bley: I would like to inquire about the relative cost of concrete construction with masonry construction as usually adopted, in the same situation, and the relative value of the two after they are done, as to durability.

Lieut. Horney: I do not know.

Mr. Bley: Did you not get any estimate of what the work would be?

Lieut. Horney: I know what one particular sandstone wall happened to cost, but I do not know what the general run of it is, have no means of knowing, but this cost was not more than one-third of what the sandstone wall cost.

Mr. Liljencrantz: I should think that would depend chiefly upon how handy it is to find suitable stone, how far that may have to be transported for one thing, and whether the wall is required to be rock-faced or fine-cut stone, etc.

President Johnston: In the work of the Chicago Drainage Canal where the stone was quarried out of the excavation, the price for masonry walls can be said to run about $3.25 and over. On Section 1 the price was $2.90 and the price for concrete walls on other sections, where the rock was taken from the excavation for crushing, has been about the same, natural cement being used in the concrete wall with Portland cement mortar facing.

Mr. Bley: Then as to the durability of the two forms.

President Johnston: That depends on the character of the stone very largely. In our case on the drainage canal we think the concrete wall perhaps will be the most durable.

Mr. Carter: I would like to ask a question regarding the locks over the gate openings, what the size of the locks was and how many were made.

Lieut. Horney: I do not believe I understand.

Mr. Carter: The locks where the two sections join; where the one section interlocked into the other.

Lieut. Horney: It was three by twelve, three inches deep, twelve inches wide.

Mr. Carter: How many locks were in the foundation?

Lieut. Horney: They were about two feet apart, running the entire length, from the rear of the counter fort to the front, making about ten of them; they were three inches deep and nine inches wide.

Mr. Carter: Would it not be practical to put a couple of copper plates across the joints and, by a fine hair line there, establish something of what that expansion and contraction would be in each case.

Lieut. Horney: I think it could be, yet you would not know exactly in what length that contraction occurred.

Mr. Carter: No, except by having a plate at each joint and by taking the average in the measurements.

Mr. Boardman: I would like to ask Mr. Harrison whether it would be practical to measure the wall that was built last year or the year before, when it is closed up in hot weather and then again the same points next winter; would that answer just as well as taking the new wall that is built this year?

Mr. Harrison: Such measurements could be made, but as Mr. Morison has said, that does not furnish the data he wants. The information, as I understand, he would like to have is, how much difference there is in the expansion of concrete and the expansion of steel or iron; how much difference there is in the expansion of the two materials under a given change of temperature. Take the wall, for instance, which is built during the summer; we can take that today and measure for the length of the wall the total amount of the openings, we could measure it again when the temperature of the day would be, say, 70 degrees; the interior of the wall may not be 70 degrees, it may be 60; we do not know what it is, we have no definite means of determining, and when the openings are measured. Next winter, when the temperature is down to zero, the interior of the wall may not be at zero, it may be 40 degrees, or may be colder; the difficulty is that you can not get a given temperature throughout the entire mass of the wall, and that would not then give the information that is desired at all. Still it might be of some interest to know how much a wall would contract from the ordinary summer weather to the extreme cold weather in the winter; that information could be had and might be useful to know.

Mr. Carter: That is what I had in mind, that it might be useful information for some other purpose. For instance, for long masonry buildings.

Mr. Bley: Along that line, is not a wall nearer what Mr. Morison would want than a block of concrete inside where it is entirely separated from the weather? As I understand it, he wants to use his concrete in connection with steel in a building. The outer surface of that building wall is certainly in contact with the atmosphere, and in that case is somewhat similar to a wall on a drainage canal where it is not under water. Now, why not bury a piece of steel in that wall and observe the two there? If that steel is well buried from the surface; it would give the condition that he is likely to want in case of a building. Now, in putting up a steel frame in a building, we do not get all the parts the same distance from the surface, you have the difference in temperature

and moisture there from the absorption of the moisture by the wall in varying degrees, and those things you would have in your large wall, either in the case of the dam or in the case of the drainage canal. It seems to me that the experiment could be made there and would certainly be of some value, and I question whether it would not be of equal value with the one in which the concrete was taken entirely separate from the weather elements of the atmosphere.

Mr. Beardsley: The wall that Mr. Harrison has referred to, it seems to me, may have tension or compression strains of unknown amounts that would modify the data perhaps considerably. The building built, as suggested by Mr. Morison, of metal, it seems to me, may be likewise under tension or compression of varying loads which will change the length of members perhaps fully as much if not more than the temperature. I think that additional observations following that line would also be both necessary and interesting.

President Johnston: The conditions surrounding any given measurements should of course be very well known in order that measurements may have any value. The influence of uncertainties as to the condition of placing the concrete may be illustrated by the condition of affairs existing at the spill-way at Summit, built by the Sanitary District of Chicago—a concrete dam 400 feet long that has never shown those expansion or contraction cracks. That dam was built in cold weather, and expansion perhaps took place, but expansion does not make cracks. Unless the conditions are very well known, the result of measurements may be very misleading. I have examined that dam at all seasons of the year, and it has never shown contraction cracks.

Mr. Boardman: In regard to the quaking feature, when the Western Society was out at Rock Island on that trip last fall, I thought I distinctly noticed quaking in one of those piers.

Lieut. Horney: All the foundations were so quaking.

President Johnston: There is one point in connection with concrete making that I had intended to speak of, and that is with regard to the question of workmanship in making concrete, and especially with regard to incorporating the sand in the cement. In our District specifications we have specified that the sand and the cement shall be mixed dry and shall be thrown through a number five sand-screen before any water is added to it, and our experience has been that that has been satisfactory.

That leads up to another point with regard to the theories on which concrete mixing machines have been constructed. I believe all of them have been constructed on the idea of getting the sand and the cement together, either dry, damp or wet, and trying to incorporate it by turning it over and over, mixing the materials together, a process that involves quite a little bit of labor, according to the amount of mixing that is done. Now in screening the sand through a number five sand screen, we get a suggestion in

regard to incorporating materials by letting them drop together. We will take the sand and cement and stone as three sheets and have the different sheets moving with sufficient velocity and we will have the ingredients dropped together so as to cause a very complete incorporation, the water being added at the last moment. I speak of this after having followed it out somewhat in calculation, and I am inclined to think that a machine of that kind might be readily built that would have a very large capacity if the material could be gotten to it, and would give an ideal incorporation without any other work than hoisting the material the different distances.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

BACTERIAL PURIFICATION BY NATURAL PROCESSES.

By PERCY FRANKLAND, Ph. D., B. Sc., F. R. S., Prof. of Chemistry in Mason College, Birmingham, Eng.

(*Proceedings of the Institution of Civil Engineers. Vol. cxxvii.: page 84.*)

(*a*) *The "Self-Purification" of River Water.*—There is probably no subject connected with the hygienic elements of water-supply which has so much engaged the attention of public authorities and excited such warm controversy amongst experts. Until a few years ago, however, the chemical side of the question was the ground upon which most of the discussions were fought out, the biological side of the subject being all but inaccessible in consequence of the rudimentary state of bacteriological knowledge. Now, however, this aspect of the subject may be surveyed also; for, by the rapid strides which have been made in bacteriology, an intimate acquaintance has been gained of the nature and habits of many of those living or organized impurities which may be present in water, and, in comparison with which, the unorganized or lifeless impurities sink into relative insignificance.

The evidence which during the past few years has been accumulated by many different observers on the most varied water-courses shows, almost without an exception, that the number of bacteria present in a running stream becomes diminished during its natural flow. This bacterial purification of running water is displayed in the investigations of Frank,[1] on the River Spree, below Berlin; in those of Prausnitz,[2] on the River Isar, below Munich, as well as those of Schlatter,[3] on the River Limmat, below Zurich, whilst the author, in July, 1892, obtained evidence of the same phenomenon in the case of the River Dee, from which the water supply of Aberdeen is drawn.

Above Braemer the Dee was found to yield only 88 micro-organisms in one cubic centimetre, and is, therefore, bacteriologically, of great purity. The next sample was taken from the river below Old Mar Castle, and after thorough incorporation of the tributary Cluny, which receives the sewage of Braemer This accession is marked by a large increase in the number of microbes, as many as 2,829 being found in one cubic centimetre. Another sample was taken above the Bridge of Ballater; and it shows that

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1 Zeitschrift fur Hygiene. Vol. iii., p. 355.
2 Der Einfluss der Munchener Canalisation auf die Isar: Munchen, 1889.
3 Zeitschrift fur Hygiene, Vol. ix., p. 56.

the number of micro organisms has been reduced by rather more than one-half in the flow from Old Mar Castle to this point, for only 1,139 were found in one cubic centimetre. A sample from the Dee, 100 yards below the Ballater sewage pond outfall, on the other hand, shows a large increase in the number of micro-organisms, as many as 3,780 being obtained in one cubic centimetre. On following the river down, a sample was taken above the junction of the Neil Burn, and it was found that the number of micro-organisms had again fallen to about the same as that above Ballater, viz.: 938 in one cubic centimetre. Before the entrance of the Neil Burn, a polluted stream, which at the time of the investigation was a mere dribble, the number of micro-organisms had perceptibly increased, 1,860 being found in one cubic centimetre. The river on reaching Invercannie, however, again exhibited just about the same number of micro-organisms as above the Neil Burn or above Ballater, only 950 being found in one cubic centimetre. The total length of the river which was covered by the examination was upwards of forty miles.

The foregoing investigation on the Dee is especially interesting, as the amount of polluting material gaining access at these several points is so small in comparison with the volume of the stream itself that it was found impossible by chemical analysis to detect any material alteration in the composition of the water of the river even immediately below each of the above sources of contamination. By means of the bacteriological examination, however, as indicated, each source of pollution was found to have produced an unmistakable, although transitory, effect upon the water of the stream.

If inquiry be made into the mechanism by which this undoubted disappearance of bacteria in running water is effected, a number of factors must be taken into consideration, which, although not necessarily all coming into play at one and the same time, or in every water-course, must yet, according to present knowledge, be held responsible for the bacterial improvement which such running waters undergo during their natural flow.

Insolation.—One of the factors to which, perhaps on account of its novelty, great prominence has recently been given in this connection is the remarkable destructive effect which the sun's rays have been found to exert on bacterial life. It would be impossible to give here a detailed description of the numerous investigations which have been made on this interesting subject;[1] but it will be necessary to review briefly several important researches which have had a direct bearing on the question. This is perhaps the more necessary because solar enthusiasts have been led, especially on the Continent, to take such an exaggerated view of the powers of insolation in effecting the bacterial purification of water, that even the discharge of untreated sewage into rivers

1 For further information see the Author's work, "Micro-organisms in Water," Longmans, 1894, chapter ix., p. 333.

and streams has been seriously counseled, in the belief that sunshine would destroy all the noxious organisms which might be present in such pollutions. Now, although the bactericidal action of light is altogether beyond question, it must in the first place be borne in mind that, so far as is now known, microbes are less sensitive to its lethel influence when they are suspended in water than when they are present in ordinary culture-media. Hence it will be necessary in endeavoring to assess the potency of the sun's rays to destroy bacteria in water, to confine attention for practical purposes to those investigations which have been carried out with microbes actually in water.

In pursuing the inquiry in this direction, the fact is at once apparent that the bactericidal action of light is not co-extensive with the penetration of the sun's rays, but is confined to the upper layers of the water upon which these rays are incident. This point has been conclusively demonstrated by Procaccini,[1] who exposed drain water containing an abundance of bacteria to bright sunshine in cylindrical glass vessels fifty centimetres in depth. The following table gives the results obtained. The exposure to bright sunshine extended over a period of six hours, from 9 A. M. to 3 P. M., in the month of June, a control-cylinder containing the same water being submitted to precisely the same conditions excepting only that it was protected from all access of light:

	INSOLATED CYLINDER. No. of microbes per cubic centimetres.	DARKENED CYLINDER. No. of microbes per cubic centimetres.
Before exposure:—		
Surface	4,900	4,900
Center	4,510	4,510
Bottom	6,781	6,781
After insolation:—		
Surface	0	7,261
Center	2	9,051
Bottom	8	12,591

Here is unmistakable evidence of the remarkable bactericidal power of the sun's rays when they are permitted to enter a cylindrical column of water, both from above and from the sides, under the most favorable conditions. It should be pointed out, in connection with this experiment, that the water employed had been previously filtered, to remove the coarser particles in suspension, the presence of which would have materially intercepted the solar rays. Indeed, the presence or absence of turbidity in a water is another circumstance which must be taken into consideration in estimating the bactericidal power of sunshine, a point to which reference will be made later.

1 Annali dell' Instituto d'Igiene Sperimentale di Roma, Vol. iii., 1893.

In another series of experiments Procaccini[1] endeavored to ascertain what part in this destruction of microbes is played by those rays which impinge upon the surface of the water. For this purpose he carefully prevented all rays from entering the sides of the glass cylinders in question, hoping thus to determine the depth beneath the surface to which the bactericidal action of the sunshine extends. The results of such experiments are given in the following table. The exposure extended over three hours (12 noon to 3 P. M.) during the month of June:

	INSOLATED CYLINDER. Number of Microbes per cubic centimetre.	DARKENED CYLINDER. Number of Microbes per cubic centimetre.
Before exposure:		
Surface	2,100	2,100
Center	2,103	2,103
Bottom	2,140	2,140
After insolation:		
Surface	9	3,103
Center	10	3,021
Bottom	2,115	3,463

Thus it was found that no reliance could be placed on the power of even Italian sunshine, when acting continuously for three hours in the height of summer to destroy microbes in water at the insignificant depth of 50 centimetres. Buchner[2], again, in some experiments made on the Starnberger lake near Munich, in water which was relatively clear and transparent compared with that employed by Procaccini, found that at a depth of 5 feet below the surface of the lake the bactericidal power of the sun's rays, although acting over a period of 4½ hours, was no more recognizable.

Another circumstance which must be taken into consideration, in forming an estimate of insolation as a purifying agent, is that a microbe's power of resistance to any given adverse conditions is largely dependent on its initial vitality and on its state of development, i. e., whether it is present in the hardy spore form, or in the form of the comparatively fragile bacillus. Thus the author has found[3] that anthrax spores produced at a temperature of 18° to 20° C. are far more resistant to sunshine in water than anthrax spores produced at a higher temperature, 35° to 38° C., whilst numerous investigators have shown that the bacilli are much more readily destroyed by sunshine than their spores. Whilst Procaccini's experiments sufficiently indicate what may be expected of sunshine in the destruction of noxious organisms in water, and whilst due credit must be given to insolation for what it can actually accomplish, it is obvious that its powers are re-

1 Annali dell'Instituto d'Igiene Sperimentale di Roma, Vol. iii., 1893.
2 Archiv fur Hygiene, 1893.
3 Report of the British Association for the Advancement of Science, 1893, p. 461.

stricted within comparatively narrow limits, especially in a climate like that of England, in which it frequently happens that for days and even weeks at a time no sunshine is recorded.

Before passing to the next factor concerned in the natural purification of water, the author would briefly point out that some interest has recently been aroused in this subject of the bactericidal action of light in connection with the relative merits of open and closed reservoirs for the storage of water. It has been advanced that if light is capable of effecting this remarkable destruction of bacteria, and that the dangers of potable water are dependent on the possible presence of noxious bacteria, it is surely only logical that all waters should be exposed to the maximum amount of light before distribution for domestic purposes, and that all reservoirs destined to contain such water should be freely exposed to daylight. It must, however, be remembered that by exposing water to light, an opportunity is thereby afforded for the direct transformation of mineral into organic matter through the instrumentality of green plants, which are only capable of flourishing in the presence of light. By thus inducing the growth of green plants, a door would, therefore, be opened to the contamination of the water with the products of decaying vegetable matter, a form of contamination which, whilst incapable of directly producing zymotic disease, is, nevertheless, quite capable of rendering a water so unpalatable as to be unfit for dietetic use, and possibly even of occasioning diarrhœa and similar ailments amongst its consumers. In spite of these recent revelations concerning the bactericidal action of light, it is, therefore, still to be recommended that the all but universal practice in vogue with waterworks engineers of storing subterranean and filtered waters in reservoirs protected from daylight should be continued, as such waters are liable to suffer most serious deterioration by exposure to this influence.

ECONOMY OF HIGHER STEAM PRESSURES.

By Dugald Drummond, M. Inst. C. E.

(*Proceedings of the Institution of Civil Engineers. Vol. cxxvii.; page 222.*)

The method adopted to determine the comparative efficiency of the different pressures was to ascertain from the indicator diagrams the weight of steam used per h. p. per hour, this being the best method admissible at present in an investigation of this kind. It would have been preferable to have taken a continuous sheet of indicator diagrams of every stroke from start to finish, as then the absolute work done by the engines would have been known and would have been comparable, but the author does not

know of any apparatus of this kind having been arranged for locomotives.

The economy obtained by increasing the boiler-pressures, apart from compounding, has been established in traffic as well as in these investigations. Mr. S. Johnson, of the Midland Railway, by raising boiler-pressures from 140 lbs. to 160 lbs. per square inch, effected a saving of fuel of between 11 and 13 per cent. Mr. J. Holden, of the Great Eastern Railway, has verified Mr. Johnson's results by the reverse process in the compound engine in lowering the boiler-pressure from 160 lbs. to 140 lbs. per square inch. The former saving of 12 per cent of fuel then dropped to 2 per cent, and if the low-pressure cylinder of this engine had been 25½ inches in diameter instead of 26 inches, so as to have the same cylinder capacity as the two non-compound cylinders they were tried against, the remaining 2 per cent would have become negative. Both these results agree closely with the 15 per cent of steam saved between the Caledonian Railway engines No. 77, with a boiler-pressure of 175 lbs per square inch, and No. 78, with a boiler-pressure of 150 lbs. per square inch, the weight and speed of the trains drawn by both engines being generally alike. Again, between engine No. 76, with a boiler-pressure of 200 lbs. per square inch, and engine No. 78, the saving effected amounts to 31 per cent, even though the speed and weight of the train were in favor of the latter. Again, between engines No. 76 and No. 77 there is a saving of steam effected by the higher pressure of 11.92 per cent.

A consideration of the conditions under which the steam does its work in both engines will not show any superiority for the compound over the non-compound engine. On this subject the phraseology of the marine engineer has been adopted and developed, although the working conditions of the marine and locomotive engine are widely different in two of the most important elements of economy, i. e., quality of steam and piston-speed. In the locomotive the steam reaches the cylinder through the highly heated atmosphere of the smoke-box, and must be in a very different condition from that finding its way into the high-pressure cylinder of a marine engine. This is manifest from the investigations of the Research Committee of the Institution of Mechanical Engineers[1]. It has sometimes been assumed that cylinder condensation and re-evaporation occur to a serious extent in non-compound inside-cylinder engines. But the steam absorbs heat from the smoke-box in passing to the cylinders, and must reach them very dry at a temperature above that of saturation. On entering the cylinder the steam from the boiler mixes with compressed steam at or above the boiler temperature. The cylinders also form part of the smoke-box, and heat is conducted through the cylinder walls as well as being generated by the friction of the piston rings. When to this is added a piston speed of 1,000

1 Proceedings of the Institution of Mechanical Engineers, 1889, p. 235.

feet per minute, equal to a train speed of 55 miles per hour, which gives a duration of one-fourth of a second for a revolution, the necessity for expanding steam in two cylinders to prevent condensation and re-evaporation is greatly reduced. It is difficult to conceive how more favorable conditions for the transformation of heat energy can exist in the steam engine. The principal factor in preventing cylinder condensation and re-evaporation is high piston speed; a speed of 1,527 feet per minute was reached during these trials with engine No. 76, at a train speed of 81.8 miles an hour.

Modern express traffic therefore offers a guarantee that condensation and re-evaporation in inside cylinder non-compound locomotives must be an infinitesimal quantity, and this is verified by the high mean cylinder temperature and the weight of steam used per H.-P. per hour, the latter comparing favorably with the best marine practice in triple expansion condensing engines. The advantage of reduction of the thermal range in each cylinder of compound locomotives is not apparent, since the steam is maintained twice as long in contact with the cylinder surfaces, and the surfaces are nearly trebled in area. Although the high-pressure cylinder exhaust absorbs heat in passing through the receiver, it is difficult to see how a high thermal efficiency can exist under these disadvantageous conditions.

During part of the running of engine No. 76, five expansions were made, the efficiency increasing to the highest point. As the whole question of engine economy resolves itself into the number of times steam can be expanded, and as in this case five expansions were within the economical limit in a single cylinder, compounding within this limit appears to be unnecessary. If, however, the thermal and dynamical conditions of the non-compound are superior to those of the compound engine, how is it that those who favor the latter system have attained superior results? The reply must be that the two systems have not been compared on a fair basis. In the first place, the boiler-pressure of the compound locomotive has been usually higher. In the second place, the driver of the compound engine is obliged to keep up the boiler-pressure, as there must be considerably less range of mean cylinder pressure than in the non-compound engine, which can expand steam as low as one-and-a quarter times, and all starting from stations is so done, whereas the compound locomotive cannot expand less than two-and-a-half times. This reduction of range in the power of the latter engine is undoubtedly the cause of reduced coal consumption over what it is to higher boiler-pressure. Other things being equal, coal consumption is the measure of the work done by an engine, and if the compound engine cannot run so fast in express traffic, or has to be assisted on up-gradients, the result should not be credited to increased efficiency. The author is of the opinion that in a comparative trial of the simple and compound systems, the boiler-pressure should be alike. The

minimum number of expansions should be alike, and the low-pressure cylinder of the compound engine should be equal to the combined areas of the non-compound cylinders. On this common basis only should the trials be conducted, and no analysis offers greater advantages than the one adopted here. He suggests that such a test should be made with engines on the compound principle against non-compound engines, say for a month's duration, in order that their respective merits may be tested in a way that will settle doubts existing on the question.

Viewing the question of steam-pressures broadly, the author has come to the conclusion that for the present, until drivers appreciate the value and take advantage of higher pressures for ordinary locomotive engines working main-line traffic economically in all respects, the pressure should not be less than 150 lbs. nor more than 170 lbs. per square inch. Pressures of 200 lbs. per square inch can, he believes, only be economically used with engines working heavy suburban passenger traffic, whereby speed can be got up quickly when leaving stations. By this means a larger amount of traffic can be worked in a given time than by engines with pressures of 140 lbs. per square inch, which is the average now used in working such trains.

THE TRANSMISSION OF POWER BY ELECTRICITY.

By WILLIAM HENRY PREECE, C.B., F.R.S., Vice-President Inst. C.E.

(Engineering, London, May 28, 1897. Pages 727-8.)

The utilization of the waste energies of nature is the highest function of the engineer. Millions upon millions of units of energy are being expended on rending rocks, on grinding stones, on changing river beds and on carving the surface of the earth into hills and valleys. Their transport to centers of civilization means not only the permanence of the structure of the face of nature, but the exercise of true economy.

The relative merits of the different modes of transmitting power can be determined commercially solely by the arbitrement of £ s. d., and scientifically by their relative efficiencies; that is, by the ratio in each case of the power utilized at a distance to the total power delivered at the source.

Supposing we have available at some convenient spot, at all hours and seasons, 100,000 gallons of water falling every minute 45 feet, it will be capable of delivering 1,000 kilowatts (1,340 horse-power). If electricity is generated from this power there will be wasted:

	Kilowatts.
In the turbine	250
" dynamo	60
" circuit	15
" motor	50
Total	375

So that of the 1,000 kilowatts delivered by the water, 375 kilowatts are wasted and 625 kilowatts are utilized at the final point of application. The total efficiency is, therefore, 62.5 per cent.

It is quite clear that the energy wasted in the circuit is to be eliminated only by taking materials to the fall, and establishing factories there. But the transport of material may cost more than the waste in the circuit. Hence, we have to compare the cost of transport against the cost of the upkeep of the line and the value of the waste of energy in it.

There are three effective modes of transmitting power—electricity, water and air. What we have broadly to discuss is their relative efficiency. How much of the total energy available at the initial or generating point can be delivered at the final or useful point? In other words, how much have we lost in transit and conversion? What price can we get for our commodity as delivered, and what profit do we make on the transaction? Each method of transmission is limited by the strength of materials, the loss of energy, the heat generated and physical difficulties overcome, the dangers to person and property, the capital expenditure and cost of transmission and delivery.

Now it is the peculiarity and value of electricity as the medium of transmission that the energy wasted on the line can be kept a constant quantity independent of its length, but the cost of upkeep must of course increase with its length. Hence the principal item we have to consider is the upkeep of the line and the capital that has to be expended on its erection.

A main of copper of 1 square inch sectional area carrying 1,000 amperes would waste in heating up the conductor 1 kilowatt (or 1⅓ horse-power) in every 40 yards. If it carry 500 amperes, it would waste the same energy in every 80 yards; and if only 50 amperes be used, in every 800 yards. Hence the value of reducing the strength of the current. It is entirely under our control, for the weight of copper in the mains for the transmission of the same power with the same loss varies inversely as the square of the pressure. A thousand volts will deliver 1,340 horse-power (1,000 kilowatts) through a square inch main at a distance of 5.6 miles, but with a loss of 50 per cent of the energy generated. Ten thousand volts will deliver the same power at a distance of 27.5 miles, and 20,000 volts will deliver it at 110 miles with a loss of 2.5 per cent. At shorter distances the waste can be reduced still further. The pressure applied as in water is limited by the strength of materials, and to the stresses brought to bear upon them. It is difficult at present to insulate more than 20,000 volts. Indeed, the maximum pressure used in England and Germany is 10,000 volts, while 6,000 volts is the apparent maximum in the United States of America. Were it practical to use higher pressures, it would be possible to deliver power by electricity at distances of about 200 miles from the place of generation, so as to compete favorably with steam. But with the present price of

coal in this country, and with practical pressures the radius of economical delivery does not exceed 40 miles.

The same argument applies as much to the actual transmission of the water itself, from the fall to the convenient spot where its energy is extracted, as it does to the transmission of the energy in the electrical form from the points of transformation to its delivery at the point where it is applied. The distance to which it is practical and economical to transport energy is thus controlled by the cost of generating energy at the given point of application, and this depends on the price of fuel at that spot. Coal is thus the predominant element.

Egypt is a typical case of the possibilities of the transmission of power by electricity. On the Nile there are at Merawi and Wady Halfa magnificent cataracts where immense quantities of energy are running to waste. Is it not possible to utilize this waste energy in Cairo or its neighborhood? Certainly it is, but at what price? How will it compare with the cost of fuel from England?

There are many instances of economical and successful utilization of water-power in the United States and Canada. The following is a list of a few typical instances:

Place. *America.*	Power-House. Horse-power.	Kilowatts.	Distance in Miles where Utilized.
Niagara	20,000	15,000	21
Sacramento	11,000	8,250	24
Ogden	11,000	8,250	36
Big Cottonwood	7,000	5,250	14
Concord	5,000	3,750	4
Portland	4,600	3,500	12
Fresno	2,300	1,700	35
Quebec	2,200	1,650	8
San Francisco	1,000	750	12

There is a remarkable example of successful transmission of power in Italy, from Tivoli to Rome, a distance of 18 miles; 50,000 gallons of water per minute, falling 160 feet at Tivoli, are equivalent to 2,400 horse-power.

	Horse-Power.
75 per cent of this=output of turbine	=1,820
90 per cent of which=output of dynamo	=1,620
18 per cent of which=loss on line	= 292
Making delivery at Porta Pia	=1,328
90 per cent of which is utilized in Rome	=1,196

Thus 50 per cent of the power of the waterfall at Tivoli is used in Rome.

Switzerland teems with successful installations, and there are numerous examples in Germany and in France.

At Foyers, Worcester, Keswick, Windermere, Lynton, electricity is obtained from water-power, but in no case is any great distance covered.

At Worcester the corporation have established their generating station for lighting the town some two miles away on the River Teme, a tributary of the Severn. Here some 250 horse-power is obtained from a 10-foot fall, and the advantages obtained through the reduction in generating costs have fully justified the experiment.

The cost of generating per unit was under 1½d., although it was necessary to generate 200,000 units out of a total of 333,000 from coal. The net cost of generating the units produced from the water was under 0.8d. per unit.

It has been proposed to burn coal at the pit's mouth and to transport the energy extracted as electric currents to London.

So far as can be seen at present, it is cheaper to transport the coal. The cost of coal does not form the sole charge in producing electricity. Management, labor, repairs, depreciation, and interest on capital expended are much more important items in steam plants.

Assuming that it is required to transmit 1,000 kilowatts, and that the total annual quantity of energy transmitted is 3,000,000 kilowatt-hours—an amount of electrical energy easily produced from 5,000 tons of coal. If the cost of transporting coal 100 miles is 5s. per ton, the annual bill for transportation will be 1,250*l.* This represents only 0.1d. per unit produced, and is less than the interest on the capital required to be expended on the construction of the line.

Power in Cities.—In most of the cases mentioned above it would have been probably impossible to transmit power otherwise than by electricity, but when the transmission of power by electricity is considered in relation to the supply of power to the inhabitants of a town, to railways and to tramways, to various separated portions of machinery, such as in large works, on board ship, in coal and other mines, the rivalry of other methods is encountered.

The advantages claimed for electricity are ease and cheapness of distribution, facility in application to nearly every type of machinery, efficiency in generation and in transformation to power, cleanliness and safety, reliability and convenience for repairs.

As an illustration of the transmission of power in large cities, let me take London as the best example, and assume that it is desired to work both the Metropolitan railways by electricity. Clearly the power-house should be on the river bank, for we must be dependent on coal, and we should be where coal is cheapest; but whether the coal be used direct as fuel, or converted into gas first by the Dowson or Mond process, is a matter for consideration foreign to this discussion.

Mr. Humphery (March 16, 1896) estimated that by the use of the Mond gas-producer plant, it was possible under certain circumstances to produce a kilowatt-hour for 0.184d., and this could

be easily distributed and applied on a coach on the railway for a cost not exceeding 1d. per unit.

For Workshop and Home Use.—The horse-power lost in shafting is little known. Mr. C. H. Benjamin, of Cleveland, tested 16 different factories of all kinds in that city. He found that from 50 per cent to 80 per cent of the horse-power developed was absorbed by the shafting before it reached the machine where it was to be utilized.

For small powers the horse from the point of convenience beats everything. But its food corresponds with the "waste" of other systems; and though, if we regard its efficiency in converting fuel into energy, it stands, perhaps, at the head, yet the price of its food and the waywardness of its health make it the least efficient of all machines in a commercial and economic sense. Oil and gas for small powers are more convenient, but not so economical as steam, while electricity, if it can be supplied at 1½d. per kilowatt-hour, is the most convenient and economical, for it is always ready if supplied from a central station. It requires no boiler, and it is accompanied by no danger. It is handy; it is placed where it is wanted, and used when it is wanted. You pay only for that which you have used. It is useful not only for small trades, but it is invaluable for domestic purposes, for sewing machines, ventilation, pumping, cooling, lifting, and for many other purposes. It is, however, but little used in England at present. High prices, ignorance and fear have kept it in the background, but it is rapidly and successfully coming to the front.

The efficiency of dynamos which transform energy into electricity, and the efficiency of the electric motor which transforms electricity into power, are unequaled. Dynamos and electric motors are now commercially made at moderate prices with efficiencies of from 94 per cent up to 96 per cent.

Broadly speaking, it may be said that there is no practical difficulty whatever in transmitting energy to great distances by water, oil, coal, gas, air, or electricity.

Their relative merits depend first on their relative efficiencies in production and application, but their financial success depends solely on the cost of transport. There are many cases where each must be paramount. There are others where the balance is questionable, and where other conditions, such as space, convenience, cleanliness, safety, silence, must be considered.

EXPERIMENTS ON A COMPOUND LOCOMOTIVE.

DYNAMOMETRIC EXPERIMENTS ON A FOUR-CYLINDER EXPRESS COMPOUND LOCOMOTIVE ON THE PARIS, LYONS AND MEDITERRANEAN RAILWAY, MADE BY M. PRIVAT IN 1895.

(Summarized translation in Engineering—London, 1897, page 828, by Mr. Bryan Donkin, from Revue Generale des Chemins de Fer, March, 1896.)

These dynamometric experiments were made on a new four-cylinder compound locomotive engine of the Paris-Lyon-Mediterranee Company. It is the first of 40 locomotives built in 1894 and 1895 from the designs of M. Charles Baudry, and differing in a few respects from the experimental locomotives of 1892. In the earlier boilers the firebox was of steel, but as this metal was not found perfectly satisfactory, it was replaced by copper, as formerly. The engine tested had two high-pressure and two low-pressure cylinders, and the pipes connecting the latter to the chimney were short and straight. One single exhaust pipe in the center of the smokebox discharged the two low-pressure cylinders and no attempt was made to heat the steam by the chimney gases. The valves of the high-pressure cylinders were arranged on the Walschaert, and those of the low-pressure on the Gooch system, without eccentrics, thus making them more easily accessible for lubrication, &c. The main object kept in view in the design of the locomotive was to reduce as much as possible the bulk of the engine and its resistance to the air, without complicating the constructive details. The chimney, dome, &c., were therefore massed together, and inclosed in one casing, and a kind of prow-shaped appendage fixed to the smoke-box. The valve gear consisted of a single piece of mechanism acting simultaneously on the four distributing valves. It was connected to them in such a way that, for each cut-off to the high-pressure cylinders, the admission of steam to the low-pressure cylinders could be varied independently of the driver. The proportional volumes of the two sets of cylinders being as 4 to 1, the admission of steam to the low-pressure cylinders was never at less than four-tenths of the stroke.

The principal aim of the experiments here described was to test whether this arrangement of the valve gear, which was known to save much wear and tear to the parts, also increased the power developed by the locomotive, and produced an economy in the consumption of fuel and of steam. The programme of the trials was drawn up to mark the variations in the power developed and the consumption of fuel when, the cut-off in the high-pressure cylinders being maintained uniform, it was varied in the low-pressure cylinders. The engine tested was therefore provided with special mechanism, by means of which the two admission

valves of the high-pressure acted independently of the two admission valves of the low-pressure cylinders, and any desired cut-off was thus produced. A drawing of this valve gear is given in the original paper. The experiments were made when the engine was running from Paris to Laroche and back. Only one set of cylinders was indicated; the pipes admitting steam to the indicators were well covered. The power on the drawbar (or useful work) was measured by two dynamometric cars. The coal consumption was not determined, because, in order to test the efficiency of the different degrees of cut-off, it seemed preferable to measure the water, a method which prevented the stoker's skill from affecting the results of the trial. The actual consumption of water—that is, the water drawn from the tender to feed the boiler for the first set of experiments—was not noted, but calculated from the weight of steam shown in the diagrams of the high-pressure cylinders at the beginning of expansion. While the indicator diagrams were being taken, the boiler pressure was maintained uniform.

As the experiments were made to determine the variations in the power developed (indicated and useful work) and in the consumption of water, the working conditions were varied as follows: For 2-10 cut-off to the high pressure cylinders, the cut-off in the low-pressure cylinders was successively 4-10, 5-10, 6-10 and 7-10. For every 3-10 and 4-10 cut-off in the high-pressure cylinders, steam was admitted respectively at from 4-10 to 7-10 of the stroke to the low-pressure cylinders. For every 5-10 cut-off to the first cylinders, it was admitted at 5-10, 6-10 and 7-10 of the stroke to the second cylinders. The maximum cut-off in the high-pressure cylinders was 5-10. The results of 86 experiments on these four positions of the admission valves to the high-pressure cylinders, and the corresponding variations in the indicated and useful work, and in the consumption of steam, are shown in Tables in the original paper, of which that in the adjoining column is a summary.

The useful pulling work represents the power available on the drawbar, the engine being supposed to be running at uniform speed, and was obtained from the work in foot-pounds shown by the dynamometric car. To this was added the power required for the locomotive and tender, and for increasing their speed, plus 10 per cent for the acceleration of the parts in motion. The weight of steam was calculated from the indicator diagrams on one of the high-pressure cylinders.

The variations in indicated and useful work as functions of the speed, and the variations in the consumption of steam per indicated and useful horse-power, are also shown graphically and plotted on curves in the original paper. Two sets of curves have been drawn for positions of the admission valves representing respectively 2-10, 3-10, 4-10 and 5-10 cut-off to the high-pressure cylinders. The work on the pistons and the useful work on the drawbar are also shown for different cut-offs to the low-pressure

Table of different cut-offs in high and low pressure cylinders. One boiler used with 133 Serve steel-ribbed tubes. Total heating surface, 1,593 square feet. Number of cylinders, four. Two high-pressure cylinders (outside engine), 13.4 in. in diameter, 24.4 in. stroke. Two low-pressure cylinders (inside engine), 21.2 in. in diameter, 24.4 in. stroke. Slide valve gear, Walschaert. Expansion gear, Gooch. Steam pressure, 15 atmospheres. Total weight, 50½ tons.

Admission of Steam in Tenths of Stroke (or Cut-Off). To High-Pressure Cylinders.	To Low-Pressure Cylinders.	Mean Speed per Hour.	Indicated Horse-Power.	Useful Horse-Power or Pull at Drawbar.	Calculated Weight of Steam per Indicated Horse-Power Hour in Cylinders.	Calculated Weight of Steam per Useful Horse-Power Hour (on the Drawbar).
		miles			lb.	lb.
.2	.4	37.0	472	220	13.6	29.2
.2	.4	54.6	668	112	13.4	79.2
.2	.4	45.0	560	179	13.2	41.5
.2	.5	49.3	640	213	13.4	40.2
.2	.6	55.8	682	223	14.3	43.7
.2	.7	53.3	700	283	14.9	37.2
.3	.4	54.9	898	322	15.1	42.4
.3	.4	38.6	708	405	14.9	26.1
.3	.4	46.0	801	382	14.5	30.5
.3	.5	57.1	979	428	15.1	34.7
.3	.6	57.7	990	458	15.8	34.3
.3	.7	55.8	937	478	16.7	32.5
.4	.4	56.0	1140	499	16.2	36.9
.4	.4	45.3	935	558	17.3	29.0
.4	.4	49.8	1045	539	16.5	32.1
.4	.5	58.6	1155	572	16.9	34.3
.4	.6	58.7	1190	640	17.3	32.1
.4	.7	58.5	1245	722	17.3	29.9
.5	.5	58.8	1422	780	17.6	32.9
.5	.5	41.6	1150	783	16.9	24.8
.5	.6	52.0	1290	798	18.4	29.7
.5	.7	60.4	1370	828	18.7	31.0

cylinders, when the cut-off in the high-pressure cylinders was the same.

It will be seen from the Table that the consumption of steam when the cut-off to the low-pressure cylinders is increased, while that to the high-pressure cylinders remains stationary, increases slightly per indicated horse-power, but diminishes on the drawbar. At a speed of 37 miles per hour this diminution is slight, whatever the cut-off in either set of cylinders. When the locomotive is running at 55 miles an hour the consumption of steam per horse-power on the drawbar is 18 per cent less with 4-10 cut-off in the high-pressure cylinders, 23 per cent with 3-10 cut-off, and 54 per cent with 2-10, the cut-off in the low-pressure cylinders rising at the same time from 4-10 to 7-10. The conclusion may be drawn that to secure economy of fuel, it is important not to allow the proportion between the admission of steam to the high and low pressure cylinders to be regulated at the will of the driver. The valve gear should be so adjusted that steam is admitted to the large cylinders at about 7-10 of the stroke. On all the high-speed four cylinder compound locomotive engines of the Paris-Lyon-Meditterranee Railway, the valve gear has now been modified to suit these conditions.

The curves representing the power developed show that when the cut-off to the low-pressure cylinders is reduced, the increased expenditure of steam per horse-power on the drawbar is due to the increased resistance of the engine and tender. To what mechanical details in the locomotive is this additional friction owing? Is it possible, by altering the construction, to reduce the passive resistance for each different cut-off? A series of experiments is now in progress to determine this point, and especially to consider the effect on the frictional resistance of the parts of:

1. The use of compensating valves.
2. Total suppression of the expansion to low-pressure cylinders, and of their valve gear.
3. Substitution of cylinders of smaller diameter for the low-pressure cylinders.

Other Experiments.—A series of supplementary experiments on the effect of the speed of the locomotive was also carried out. During four consecutive days the engine drew eight trains between Paris and Laroche. The mean power on the drawbar and weight of feed water during the journeys were measured, the latter by gauging the contents of the tender at the beginning and end of the run, the water in the boiler being brought to the same level at these times. The power developed on the drawbar was calculated from the readings of the dynamometric car. The admission of steam to the small cylinders was varied at the discretion of the stoker; the cut-off in the low-pressure cylinders was 4-10 on the first day, 5-10 on the second, and increased to 7-10 on the fourth. The following table gives the results of the run of about 2¼ hours from Paris to Laroche.

TABLE *on the Effect of Speed in Locomotives, the Cut-Off in High-Pressure Cylinder Being Varied.*

	Cut-Off in Low Pressure Cylinder.	Speed per Hour.	Power Developed on the Drawbar.	Actual Water per Hour per Useful Horse-Power on the Drawbar.
		miles.	horse-power.	lb.
First day......	.4	41.82	265	40.43
Second day....	.5	42.68	262	38.65
Third day.....	.6	42.81	253	36.87
Fourth day....	.7	42.70	265	36.56

In these experiments the mean speed and the power on the drawbar were practically the same, but the water per useful horse-power diminished regularly from day to day, the maximum difference being 9 per cent. In these journeys, however, the mean speed was only about 42 miles an hour, while it is at speeds of 55 miles an hour that the greatest economy is obtained, by admitting the largest quantity of steam per stroke to the low-pressure cylinders.

The ratio of the power developed in the two sets of cylinders with this new system of valve gear for varying the cut-off is an interesting study. At an average speed of about 48 miles an hour, and with from 2-10 to 5-10 cut-off in the high-pressure, and 7-10 in the low-pressure cylinders, the proportional power developed in them varied from 5½ (with the greatest difference in the cut-off) to 1½ with the smallest difference. The pressure in the intermediate receiver rose from 2 lb. to 6.3 lb. These figures prove that, with a small quantity of steam admitted to the high-pressure cylinders (or a cut-off at 2-10 of the stroke), the power developed is much above unity. As the admission of steam in both cylinders approximates, the ratio falls, and would probably be equal to unity if there were a uniform cut-off at 7-10 of the stroke. The pressure in the intermediate receiver is less, the less steam is admitted to the high-pressure cylinders.

In conclusion, the author observes that if the locomotive is worked at maximum power, the new method of regulating the cut-off tends to divide the power equally between the two sets of cylinders, when the engine is running at low speed, that is, with much steam admitted to the high-pressure cylinders. The work done in the large cylinders diminishes progressively in exact proportion to the increase in the speed; that is, as the cut-off to the small cylinders decreases. Thus, in engines running at very high speeds, only a small proportion of the total work is obtained from the large cylinders, and the engine practically works as if there were no expansion cylinders at all.

The original paper is illustrated with indicator and other diagrams, and drawings of the engine and boiler,

STANDARDIZING THE TESTING OF IRON AND STEEL.

(By P. Kreuzpointner. Engineering Magazine, 1897—756 to 759.)

Amid the lavish praises of the civilizing influences of steam and electricity, it is well not to forget the merits of the vehicles by the aid of which we are enabled to make these civilizing agencies practically useful for every-day life. Iron and steel being the transmitters and conveyers of electricity and the expansive force of steam, these metals may be considered the foundation upon which the superstructure of our intellectual and material life rests and moves.

What is it in the nature of iron and steel that enables these metals to perform the herculean task of carrying the world's commerce and industry, and to meet and ward off successfully the impetuous onslaught of sudden impact as well as the invisible, but none the less active, forces of measureless strains, which gradually weaken and undermine the strength and soundness of these metals? Indeed, endless are the disguises under which the enemies of iron and steel try to cause a break or a wreck. And since, however stubborn the resistance, wear will eventually cause the breakdown of the strongest structure, a cloud of invisible particles of iron and steel is strewn along their paths to the grave.

Considering the ever-active forces at work to destroy metals, and the ever-present necessity of reducing cost, the engineer has a continual battle with the problem of so building his structure as to secure the greatest safety and durability and consume the least metal. Familiarity with the qualities of iron and steel is, to both engineer and manufacturer, a question of the survival of the fittest.

When inquiring into the serviceableness of iron and steel for structural purposes, it is well to free our mind from the idea that these metals are rigid, immovable bodies with a power of resistance that does not change until they are worn out or break under an overwhelming force. Contrary to the popular theory, iron and steel are sensitive, susceptible to outside impressions—sometimes giving way readily to the influence of gentle persuasion. The fact is that all metals, even the hardest steel, are plastic and elastic, their plasticity and elasticity differing only in degree, not in kind. In other words, iron and steel flow like viscous bodies, under the application of sufficient time and pressure, or heat—some grades more quickly than others. Nor does it take very great pressure to set even very hard steel in motion. If, however, a not too great pressure be taken off before any permanent distortion has taken place, the metal will return to its original shape or dimensions, and, according to the greater or less degree in which a metal does this, the more or less it is elastic. This

difference in the elasticity of iron and steel is again, like plasticity, one of degree only, not of kind, though, the greater the degree of plasticity of a grade of iron and steel, the less the pressure necessary to make it flow, the less the degree of elasticity. The elasticity of iron and steel decides their value for a given purpose, and the engineer who knows best how to make use of that property and the best method of ascertaining its degree will, other things being equal, build the safest and most durable structure, because it has been proved that, as long as a structure is not strained beyond the elastic limit, it is practically indestructible.

Iron and steel are very much averse to having their virtues pried into and measured by thumb-rule. They must be approached with the delicacy that we show in approaching a high-bred, sensitive person.

That this is no mere figure of speech may be strikingly shown by an instance that came under the personal observation of the writer. At one time he was testing a bar of spring-steel 1 inch wide, 3/8 inch thick, and 20 inches long, with a tensile strength of 110,000 pounds per square inch. To ascertain the elastic limit, suitable micrometers measuring to the ten-thousandth part of an inch had been attached to the ends of the test-piece with wires leading to an electric bell and so causing it to ring whenever the points of the micrometers came in contact. When the piece was stretched, however slightly, contact was broken, and the bell ceased to ring. The number of revolutions of the screw necessary to renew contact indicated the amount of stretch for a given load. Just at the beginning, the test was stopped. Some visitors coming in, one of them explained how test-pieces are pulled apart, and, in the course of his explanation, picked up the spring-steel test-piece and pulled at the ends with both hands to indicate the action of the testing-machine. Thereupon the electric bell ceased to ring. The gentleman had stretched or bent the piece sufficiently to break the contact. It seemed incredible that any person could stretch a piece of spring-steel 1 inch wide and 3/8 inch thick with his hands. But there was no doubt about it. It was tried again and again by various persons, and the experiment succeeded almost every time. Now, if a man can stretch or bend a piece of spring-steel with his hands, what must be the effects of heavy loads?

And yet there are not a few persons, with knowledge and without knowledge, who denounce testing as a superfluous refinement of some cranky engineer, or who admit testing as only a sort of necessary evil, to be executed by any method or no method, as fancy may dictate.

With Bauschinger's celebrated mirror apparatus, it is possible to measure stretch to the 1-25000 part of a millimeter, and it has been found that, even with the small loads necessary to stretch a piece of steel to that trifling extent, there is still a permanent set

taking place. In other words, there is, theoretically, no elastic limit. In practical engineering, however, these small stretches are not taken into consideration, and it has been agreed to call the elastic limit that point where the stretch begins to increase faster than the load.

For instance, if the load applied is 10,000 pounds, and the stretch is 1-1000 of an inch, stretch and load are still proportional to each other, and the elastic limit has not yet been reached. But, if the load is 11,000 pounds and the stretch is now 13-10000 of an inch, load and stretch have become disproportional, and the elastic limit is supposed to have been reached. In every-day practice, however, we have to deal not only with this comparatively simple question of ascertaining the quality of a given metal, or grade of metal, but with the processes of melting, heating, rolling and cooling, which introduce a multiplicity of variations in quality of greater or less influence on its durability for a given purpose, and therefore more or less complicate the work, ascertaining its reliability.

So far I have attempted briefly to show that iron and steel are not the rigid, immovable, uniform bodies that many suppose them to be. As a consequence of this plasticity, it has become imperative, on account of the ever-widening circle of application, to carefully ascertain the suitability of the various grades of steel for various purposes.

It is well known that this is done by pulling, twisting, bending, nicking, punching, etc. It does not seem to be so well known, though, that not every method is suitable. In the absence of an agreement as to the best method, much time and money are spent with no other effect than that of needlessly increasing cost of production. Economic conditions have imposed upon us the necessity of adopting uniform methods in commercial transactions and industrial pursuits.

We have uniform measures of quantity; why not also uniform measure of quality of metals? The yard or meter, pound or kilogram, quart or liter, are the same everywhere. But the quality of a ton of steel is determined chiefly by the more or less fragmentary knowledge the engineer or consumer may happen to possess of the properties of steel, or, in some instances, by mere opinion and fancy. If we add to this the honest differences that may arise as to the value of a certain method of testing—differences due to the fact that one engineer has to deal more or less exclusively with one class of metal, and thus is apt to jump at conclusions and apply his observations to all similar materials—then we have, as a result, a hotch-potch of opinions and methods not at all warranted by facts, or creditable to our intelligence. Thus we have a different measure of quality of steel in every state and city, and we often find different measures in the same building, if not in the same engineering office. As Mr. E. Schroedter, secretary of the Society of German Iron Masters, said at

the last convention of the International Union for the Unification of Methods of Testing: "The specifications for iron and steel for all kinds of construction vary not only in the different industrial countries, but, on closer examination of the details of the individual specifications, an extraordinary difference is found.

"While a strength of 72,000 pounds per square inch is asked for in one case, another purchaser prescribes 112,000 pounds per square inch. For structural material which is used in hundreds of thousands of tons for bridges and buildings, one engineer asks for material of 57,000 pounds per square inch with an elongation of 20 per cent in 8 inches, while another one asks for 71,000 pounds per square inch.

"Still greater differences are found in specifications for sheets and steel castings. Not only are there great differences for quality, but there are also no uniform methods of testing and inspection."

While writing this, there march before the writer's mind, in single file, nine different test-sections of boiler steel, to measure the quality of steel for boilers. There may be others of which he does not know. Now, has boiler steel changeable properties, so that nine different measures are required as a guarantee, or is each of these measures correct, giving a true insight into the ability of the metal to resist pressure, and the effect of contraction and expansion to which steel in boilers is subject?

For other classes, two, three or four different specifications have to be filled. In a certain steel works where tires are rolled one hundred and twenty-eight sets of rolls are available, in order that all fancies may be suited. Allowing a liberal margin for necessary variations and individual judgment, thirty sets should be ample.

Who will eventually pay for the cost of making and maintaining the extra ninety-eight sets of tire-rolls, and the bother of using and changing them? Transportation, of course, will be burdened eventually with that cost. If it be urged that the cost per pound, distributed over the total number of pounds produced, is small, then why practice economy in any department of manufacture or transportation? Once the fact is fairly understood that we may get erroneous results by one method and reliable results by another, we shall have made a long stride forward to the unification of methods of testing. The object of all our testing and inspection of iron and steel, with but few exceptions, is to ascertain the rate of flow of a given metal and the force or load necessary to make it flow. The former indicates the degree of its ductility, and the latter its strength. Does a piece of metal or test-piece, representing a larger quantity of the same metal, show the same rate of flow under all circumstances, in whatever shape or at whatever speed the piece of iron or steel may be tested? It does not. If the test-piece is not of the proper size and shape, the flow will vary as the size and shape of the test-

piece, and, if it takes more pressure or load to make the metal flow in one test-piece than in another, that test-piece will be faulty, and the result of the test will be erroneous and misleading by the difference in the loads respectively necessary to make the metal flow in a properly shaped and an improperly shaped test-piece. In other words, the results of one test will be different from those of the other test, other things being equal, and the engineer or consumer may deceive himself by just that difference.

If that difference is less than it ought to be, he assumes his material to be weaker than it really is, and takes more metal than he needs; if that difference is more than it ought to be, then the engineer assumes that his metal has greater strength than it really has, and his structure will be weaker than it ought to be. The criterion, therefore, of the most reliable method of testing is the selection of a test-piece of such shape and size that the metal will begin to flow, and flow at the same rate, under a pressure approximately equal to that which would cause the same metal to flow in the structure itself.

In the above we have not taken into consideration the factor of speed and other minor influences which go to make up the value of a proper method of testing.

To illustrate the foregoing, let us assume that the engineer has based his calculations upon a limit of elasticity of, say, 30,000 pounds per square inch, and a breaking strength of 55,000 pounds per square inch. Now, if the method of testing, including shape of test-piece, speed of testing, and all other factors that may influence the result, show the metal to have a limit of elasticity of 38,000 pounds per square inch and a strength of 58,000 pounds per square inch—and such differences can easily be produced—then it is evident that the engineer is tempted to reduce the dimensions of his structure to save metal, and thereby make it too weak.

Now, since we have seen that there should be a uniform and standard shape and size of test-piece and methods of testing, how can we determine the proper dimensions of test-pieces, leaving out of consideration minor details? If we take a beam, an eyebar, a rail, a girder, an axle, or a tire, and test it to destruction, noting carefully the behavior of the metal at the various stages of the performance, we learn when and how the structure begins to give way.

CONCRETE IN RELATION TO MARINE WORKS.

By JOHN KYLE, M. Inst. C. E.

(From Engineering—London, 1897, page 833.)

In a period extending over 40 years, and having handled over 1,500,000 cubic yards of hydraulic lime and Portland cement concrete at home and abroad, the author has observed the following facts.

To induce discussion, he will open the subject under three heads, and their subdivisions as follows:

First, the treatment of concrete in the yard; second, the treatment of mass-work under water; third, the treatment of block-work under water.

First: Cement.—The chemical constituents of a sample from every 300 tons delivered being approved by the analyst, the cement was bulked 3 ft. thick in a dry store upon a timber floor raised 2 ft. above ground, turned over weekly, and used after four weeks. Cement improves by keeping, and increases in bulk by repeated turnings. For fineness, 2,500 meshes per square inch; residue, say, 7½ per cent; weight, say, 116 lbs. to 118 lbs. per bushel, testing three briquettes each from every 150 tons delivered, say 350 lbs., 500 lbs. and 750 lbs. per 1½ inch square, in two, four, and seven days respectively. In practice test results showed coarsely and finely ground cement equal. Aged cement gives poorer day-test results, but higher monthly and longer tests.

Water.—Salt or fresh water is equally suitable. Enough should be used to form a stiff pasty condition when it leaves the machine or hand. Thames or other river water has no detrimental effect upon concrete. Too much water, when evaporated, induces honeycombing or drowned cement putty, which, when pressed by water, comes out and leaves the concrete pervious to water. This had been called decomposition of the cement.

Proportion of Materials.—If of Thames or other good ballast, the proportions may range from 6 to 8 parts ballast to 1 cement, or if of hand-broken road metal, say, 4 parts to pass a 3½-in. ring, 2 to pass 1½-in., and 2 gritty sand and 1 of cement. The ballast should not contain more sand than twice the bulk of cement employed. The best materials for concrete are whinstone or granite, if freed from floury dust.

Mixing.—If machine-made, 16 to 20 revolutions, and if hand-made, turned twice dry and three times wet, when a pasty condition is secured.

Bonding in Moulds.—The mould being thoroughly cleaned inside, coated with soft soap and water, the floor strewn with sandy ballast, and the Lewis-core pieces set up, the concrete is discharged from a wagon or crane skip into the mould. Two men

inside level, tread down, and with a shovel work the concrete to the mould sides to insure a clean face when stripped. In four days the mould is slackened off the block, and in four days more the block is ready to be lifted. Every block mould should be filled and finished off the same day. For experiment, one mould should be half filled at closing time and filled up the next morning, when it will be observed that a film of drowned cement putty divides the mass into two pieces, which will never become monolithic. If a depth of, say, 2 in. is cleaned off in the morning, and fresh concrete added, it may bind, but will never be equal to the mould filled and finished the same day.

Second: "*Mass-Work under Water.*"—*In the Open.*—The success of mass-work under water is necessarily uncertain. All concrete lowered in movable-bottomed skips through water should be well mixed and charged with water. The skip should be rested on the bottom, the trigger withdrawn, and slowly raised until discharged. If carried ahead, this work will occupy 12 hours by day and rest 12 hours by night. A film of drowned cement putty is formed on the surface during the night, and all expectations of a bond will be futile.

If a block cannot be made monolithic in the yard without removing this film, it is difficult to conceive how it can be accomplished under water. Tidal currents will remove this surface film and cement, and leave exposed uncemented ballast, and therefore such is fatal to mass-work under water.

Inclosed.—Inclosing in timber compartments will hardly better matters. Doubtless the destructive effects of under-water currents may be modified; but where is the bond between each alternate 12 hours' work? It may be argued that each day's work is similar to a block set dry, in the usual way; but, then, will each skipful be found to bind up with its predecessor?

Bag-Work.—Inclosing concrete in canvas sacks and lowering into deep water is another mode of treatment. Is the binding difficulty avoided in this case? Before a large bagful is deposited the concrete has partially set, and when it has adjusted itself to the sinuosities of the new surfaces, the mass becomes a bag of fragments, through and around which the inrushing water plays, drowns the exposed cement, thus preventing the resetting and the reformation of the concrete into a monolithic mass.

Third: "*Block-Work under Water.*"—About this work there is no uncertainty. Before setting under water blocks of 20 and 32 tons should age respectively four and eight weeks, as at Dover and Colombo. Should clean ballast and whin or granite be procurable, the strongest blocks are made with flat spawls as displacers, well shaken into the concrete, and laid not closer than 6 in. in every direction. With hand-metal, displacers are not so necessary. Blocks should be, say, from 2 to 24 times longer than their depth, and their bond not less than one-third of a block. From 20 to 50 tons each is a good weight. When heavier, the question of stabil-

ity of the setting stage became a serious element where great depth of water, least resistance to, and head room for, the storm seas are considered. Progress made in Colombo was 30 blocks, and in Dover 45 blocks set in a day, and the maximum at home may be estimated at, say, 50 blocks in seasonable weather.

Durability.—In Colombo several 7-ton prison, hand-made blocks were broken up and cast into the sea in shallow water, and remained there for seven years. From one of these a 12-inch cube was cut and dressed and sent to the Melbourne Exhibition of 1880–81; to this the committee awarded a diploma of merit for excellence of work and material. The breakwater proper was commenced in 1875 and completed in 1885, and to date, now 22 years, there are no symptoms of deterioration in the concrete above or below water level, nor has the author, in other works, experienced a yard of concrete suffering from deterioration of quality from the action of sea water.

Setting Machinery.—The breakwater at Colombo was founded on a rubble base deposited in 42 ft. of water, upon which were set the concrete blocks. The setting machine was an over-end type, without staging. The progress made in the last three seasons of 120 days each was close upon 3,000 lineal feet. The breakwater at Dover finishes in a similar depth, and is founded 3 ft. into the solid chalk. This is worked from a piled timber stage driven in advance of the scar end, and the progress made in a season of, say, 240 days, is nearly 500 lineal feet.

Wet and Dry Docks, &c.—Graving and wet dock walls, tanks, reservoir dams, etc., may be set upon water-bearing foundations, provided that water pressure is prevented for, say, one week, for every foot thickness of concrete. At Dover an 8-ft. cylinder is sealed under water with 4½ ft. of 2 to 1 cement concrete, and in 60 hours the water is drawn and leaves a 40-ft. head outside without damage. Failures would disappear in presence of these precautions, provided the cement is undoubted. Over-sanding concrete is a source of much calamity. As an experiment, 1 bushel of ballast should be thoroughly water-washed through an eighth sieve; that which passed was sand, and the residue stones. Concrete should contain, after separating the sand from the ballast, 2 parts of sand and 1 of cement; the quantity of stones varies according to value, but the sand and cement never. An aggregate of 2 of sand to 1 of cement by measure should fill the interstices of the other material employed.

MEDIUM STEEL VERSUS SOFT STEEL.

By J. A. L. WADDELL, M. Am. Soc. C. E.

(From a Study in the Designing and Construction of Elevated Railroads, Etc.)

(Trans. Am. Soc. C. E. Vol. xxiii. No. 1, Page 4.)

At the outset it was necessary to determine whether it is more economical to use unreamed soft steel at a low intensity of working stress, or reamed medium steel at a higher intensity. This question was quickly settled in favor of the medium steel, which can be strained legitimately 10 per cent higher than the soft steel, and costs practically the same per pound at the rolling mills. The ratio of weights of structure for designs in medium steel and soft steel is about as 93 to 100, a saving of 7 per cent in weight of metal in favor of the medium steel. Assuming the price of metal erected to be 3 cents per pound makes the saving in pound price 0.21 cent, while the cost of sub-punching and reaming varies from 0.1 to 0.2 cent per pound, according to the facilities of the bridge shop for doing such work. At present perhaps there is a slight difference in the pound prices erected of soft and medium steel in favor of the former, enough possibly to offset the net saving by reduced weight of the latter, so that, as far as the total cost is concerned, it is immaterial whether unreamed soft steel or reamed medium steel be adopted.

There is another point involved here, however, which is of far greater import than mere economy in cost of erected metal, viz., the proper matching of rivet holes in the component parts of built members. For several years the author has favored the sub-punching and reaming of all metal (although he has not always insisted thereon), not so much for the sake of the somewhat disputed benefit derived from removal of cracked metal by reaming as for the greater certainty of obtaining properly matched rivet holes. His late investigations in this line, made by examining the shop work of the various bridge manufacturing companies of this country, both personally and through his assistant engineers and inspectors, confirm him to such an extent in this opinion that he is now prepared to make the following statement and to invite both criticism and denial thereof.

All structural metalwork, whether it be medium steel, soft steel, or even wrought iron, should be punched at least ⅛ inch less than the diameter of the cold rivet and reamed to a diameter 1-16 inch greater than same; and there is no bridge shop in existence which can turn out truly first-class work without sub-punching and reaming or drilling.

Even when the greatest care is taken in punching the metal

of the component pieces of long members, many of the rivet holes will fail to match by as much as ⅛ in., and the author has within a year or two seen ⅞ in. rivet holes elongated to 1¼ ins., merely to admit the rivets. Where several component pieces containing badly matched rivet holes are placed together and a tapered flexible reamer is used to enlarge the hole sufficiently to admit the rivet, the latter cannot possibly fill completely the irregular hole, and, therefore, if left in the piece, cannot act effectively. If condemned by the inspector on account of looseness, and then driven out, it will, on account of its crookedness, materially injure the metal about the hole and thus weaken the structure, perhaps doing more damage thereto than would the leaving in of the loose rivet.

The use of a tapered, flexibly connected reamer is all humbug, and is not true reaming at all, but merely a means of making it practicable to get the rivets through badly punched holes that assemble irregularly.

Real reaming can only be done with rigid reamers or drills that remain at all times at right angles to the surface reamed, and cut a cylindrical instead of a tapered hole. Such reamers as these are the only ones that ought to be employed on first-class metal-work, excepting, of course, in confined spaces where they cannot be used, and where the flexibly connected reamer must of necessity be employed.

The author knows well that these opinions are at variance with those of a majority of the manufacturers of structural steel, and it is on this account that he presents them so forcibly, hoping that those who differ with him will be induced to say so, and to give their reasons for so doing. At the same time he would be pleased to have those manufacturers who agree with him endorse his opinions in the discussion.

That many manufacturers are opposed to sub-punching and reaming was shown very clearly at the lettings of the contracts for the Wabash Avenue Extension of the Lake Street Elevated, and for the Northwestern Elevated, one manufacturer going so far as to make a difference of one-third of 1 cent per pound between reamed and unreamed work.

At these lettings good evidence was also given confirming a statement of the author, viz.: "It has been hitherto the general opinion that almost any kind of a structure in respect to design, quality of material and workmanship will suffice for an elevated railroad." One manufacturer remarked to the author in criticism of the plans and specifications submitted to bidders: "Why, your requirements in regard to details and workmanship are as rigid as if you were about to build a railroad bridge." The reply to this was, "Yes. I consider this structure to be just as important as any railroad bridge ever built."

And why should it not be just as important? Are not the live loads thereon more continuously applied, and is not the assumed

maximum load very nearly reached many times per day? On these accounts, is it not even more important to make an elevated railroad absolutely perfect in every detail of design and construction than it is to make a railroad bridge? The author would like to have this stand which he has taken criticised by those who disagree with him; for, if he be wrong, he ought to be corrected; while if he be right, the general practice of building elevated railroads ought to be modified fundamentally.

The author is by no means alone in his opinion that nearly all the elevated railroads of this country will, in the not very distant future, have to be replaced, and mainly on account of faulty detailing. Of what the faulty detailing consists will be dealt with further on.

At this point the author wishes to call attention to a very reprehensible practice, which these lettings exemplified quite forcibly, viz., attempting to overthrow the engineer's plans and specifications submitted for tendering. In the case of the Wabash Avenue Extension letting a most determined but unsuccessful effort was made to alter the author's plans, so when the specifications for the Northwestern Elevated were drawn, the following clause was inserted with the permission of the president of the company:

"All work herein outlined is to be done in strict accordance with the following specifications, the accompanying plans, and such instructions as may be given from time to time by the company's engineers. Bidders are hereby warned that they will be held strictly to the spirit of these specifications, and that it will be bad policy for anyone to bid with the expectation that concessions will be made after the contract is closed, in order that the work may be cheapened; for while the company's engineers desire at all times to aid the contractors in every legitimate manner to do their work expeditiously and economically, at the same time they have given these plans and specifications the most thorough consideration, and know exactly what they need in respect to both design and quality of materials and workmanship. On this account bidders are respectfully requested not to complicate their tenders by putting in alternative bids based on proposed changes in either plans or specifications; because such alternative bids will not be considered."

The result of the insertion of this clause was rather amusing, for attempts were made to overthrow not only the plans, but the specifications also. However, but little difficulty was encountered by the engineers in throwing out all alternative bids, and the contract was let to parties who were willing to tender without suggesting changes in the plans and specifications submitted to the bidders.

Another question that came up at these lettings was that of using acid or basic open-hearth steel. Preference was given to the former in the specifications, but such evidence was submitted

to the engineers as to convince them that the basic product can be made as satisfactorily as the acid, and at a trifle less cost; consequently, it was adopted. Since then, however, the reports of the company's inspectors indicate that the basic steel is not quite so uniform in quality as the acid, and that it may prove advisable in future specifications for basic medium steel to reduce the average ultimate stress limits from 64,000 pounds to 61,000 pounds per square inch.

It appears to the author that the general adoption of basic open-hearth steel is fast tending to the employment of soft steel for bridges. As far as short and medium spans are concerned, this is all right, but it is the opposite for long spans, especially for very long ones, where the dead load is the ruling factor in proportioning the members. Perhaps in the near future some alloy of steel, such as nickel steel, can be made cheaply enough to warrant its use for very long span bridges.

ABSTRACT OF MINUTES OF THE SOCIETY,

REGULAR MEETING—5TH OF MAY, 1897.

A regular meeting (364th) of the Society was held Wednesday evening, the 5th of May, 1897, in the rooms of the Technical Club, 228-30 So. Clark Street, Chicago. President Thomas T. Johnston in the chair.

The Secretary reported for the Board of Direction the election to membership in the Society of Messrs. Henry E. Vanderlip and Henry W. Carter, and the application for membership of Mr. Junius S. Dixon.

The paper of the evening, on "Rope Transmission," by Mr. Staunton B. Peck, was read by the author, followed by discussion which was participated in by Mr. John Walker, Mr. Peck, Mr. Byron B. Carter and others.

On motion, the meeting adjourned.

MEETING—26TH OF MAY, 1897.

A meeting (365th) of the Society of an informal character was held at the Technical Club rooms, on the evening of Wednesday, the 26th of May, 1897, to which ladies were invited. President Thomas T. Johnston occupied the chair. There were present over 100 members and guests. About 25 ladies graced the occasion.

Mr. C. G. Burton, of the Central Electric Company, gave an entertaining and instructive talk on the "X Ray." He was provided with apparatus and illustrated his remarks in a practical manner. At the conclusion of the paper, the stereopticon was used to present more vividly the power and use of the "X Ray." Before the exercises closed, Mr. Burton arranged his electrical apparatus so that all who desired had opportunity to look through the flesh at their bones. The subject of the evening was presented in clear manner and was thoroughly enjoyed by all present. On motion the meeting adjourned.

NELSON L. LITTEN, *Secretary.*

REGULAR MEETING—2ND OF JUNE, 1897.

A regular meeting (the 366th) of the Society was held in its quarters in Monadnock Building, at 8 o'clock, Wednesday evening, June 2d, 1897, President Thomas T. Johnston in the chair.

In the absence of the Secretary, Mr. Liljencrantz was, on motion of Mr. J. J. Reynolds, appointed to act as Secretary pro tem.

The minutes of the previous meeting were read and approved.

The Secretary reported that at a meeting held by the Board of Directors on Tuesday, June 1st, 1897, Mr. James S. Dixon was declared elected a member of the Society. Applications for membership were received from Messrs. George C. Waterman and Edward S. Jenison. These were referred to the membership committee.

The chair announced the death of Mr. A. H. Perkins, a member of the Society.

Mr. J. J. Reynolds moved that a vote of thanks be tendered Mr. C. G. Burton of the Central Electric Co., for his very interesting and instructive discourse on the X Rays at the previous meeting. Carried unanimously.

Lieut. Odus C. Horney, of the U. S. Ordnance Dep't., was then introduced by the Chair and presented a very interesting paper on the "Government Concrete Wing-dam" at Rock Island, Ill. The reading was followed by a discussion, participated in by the Chair, the Author, Profs. Feldman and Bley and by Messrs. Carter, Morison, Harrison, Keating and Boardman.

Mr. J. J. Reynolds moved that a vote of thanks be extended to the author, Lieut. Horney, for his valuable paper. Carried unanimously.

Mr. Reynolds also moved that Mr. C. L. Harrison be appointed a committee of one to make experiments, with a view to ascertaining the extent of expansion and contraction of concrete, under changes in temperature, and report at some future regular meeting. Adjourned.

G. A. M. LILJENCRANTZ,
Secretary pro tem.

LIBRARY NOTES.

The Library Committee wish to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid in completing valuable volumes for our files.

Since the last issue of the Journal, we have received the following as gifts from the donors named:

U. S. 11th Census. Part II, Vital Statistics, 1890.
U. S. 11th Census—Insane, Feeble-minded, Deaf and Dumb and Blind, 1890.
U. S. Bureau of Statistics, Consular Reports, May and June, 1897.
U. S. Special Consular Reports—Money and Prices in Foreign Countries, Vol. XIII, Parts 1 and 2.
U. S. War Dept.—Report of Test of Metals and Other Material for 1893-4-5.
Catalogue of the University of Wisconsin for 1896-7.
Illinois for 1896-7.
Calendar of the University of Michigan for 1896-7.
Librarian of the School—Proceedings Engineering Society of the School of Practical Science of Toronto, 1896-7.
Alfred Noble—Nicaraugua Canal, Hearing before the Committee on Interstate and Foreign Commerce. House of Representatives, 1896.
W. S. Hancock, Comptroller, N. J.—Railroad and Canal Report, State of New Jersey, 1896.
Onward Bates—Minutes of Convention of Employes, Bridge and Building Department C. M. & St. P. Ry., held January 20-21, 1897.
R. W. Pope, Secretary—Transactions of the American Institute of Electrical Engineers, Vol. XIII, 1896.
J. H. Shedd—Annual Report City Engineer, Providence, R. I., 1896.
Progressive Age Pub. Co.—Entropy Temperature Analysis of Steam Engineering, by Sidney A. Reeve, M. E.
Report of State Board of Health upon Sanitary Condition of the Neponset Meadows, Mass., 1897.
Authors—The Synchronograph, by Albert C. Crehor, Ph.D., and Geo. O Squier, Ph. D.
J. W. Beardsley—3 copies Engineering News and 7 copies Engineering Record.
Wm. S. Love—19 numbers Journal of Assn. Eng. Societies, 1893-4-5.
26 numbers Engineering News, 1896.
9 numbers Engineering News, 1897.
Street Ry. Review, January, February and March, 1897.
Hiero B. Herr—49 numbers Engineering Record, 1896-7.
Dept. Interior U. S.—The Water Resources of Illinois, 1895-6.
S. S. Greeley—Pacific Coast Pilot, Alaska, 1879.
37th, 38th, 39th, 40th, 41st and 44th Annual Report on Railroads, Connecticut.
Treatise on Limes, Hydraulic Cements and Mortars; Gillmore, 1890.
Report of the Bureau of Statistics, Illinois, 1894, 2 copies.
Geological Survey of Illinois, Vol. I, 1873.
Main Drainage Works, City Boston, Mass., 1885.
" " " " " " 1888.
Sewers and Drains, J. W. Adams, 1880.
Newark Aqueduct Board; Report on Additional Water Supply, 1879.
Geological survey of New Jersey, Vol. I, 1888, 1889.
Notice Historique sur le Pave de Paris, S. Dupain, 1881.
Wood Pavement in the Metropolis, Stayton, London, 1884.
Proposed plan for a Sewerage System, Providence, R. I., 1884.

Journal of the Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

Vol. II. AUGUST, 1897. No. 4

XI.

LIMESTONE SCREENINGS IN CEMENT MORTAR.

A series of tests made by Prof. Arthur N. Talbot, M. W. S. E., by request.

Read July 7th, 1897.

Sirs:—At your request, I have made an investigation of the strength of concrete made with limestone screenings in place of sand and herewith present the following report:

The object of the investigation was to determine the value of limestone screenings in concrete and the effect of the substitution of screenings for sand on the strength of the concrete. In order to be able to make a proper comparison, for every test block made with screenings another test block was made with the same constituents except that sand was substituted for the screenings. In order to determine whether the effect was a general one, both Portland and Louisville cement were used, and both short- and long-time tests were made. The tests made were for crushing strength, though a few tests of concrete beams were made. In making the concrete blocks, in protecting them during the setting, and in crushing the blocks, every effort was made to keep the conditions uniform, and it is believed that the results are as reliable as it is possible to get with such materials.

For the concrete, broken limestone, of an average quality and size, 75 per cent of it passing through a 1-inch ring, and only 1.5 per cent not passing through a ¾-inch ring, was used. 47.6 per cent of the volume occupied by the stone was voids. The sand was clean sharp sand, of a quality better than is used on public work. It contained 29 per cent voids. The mechanical analysis is given in Table XV. The limestone screenings used was nearly free from dust. As seen by table, only 5.5 per cent passes through a screen having 20 meshes to 1 inch and 2.2 per cent passed through a screen having 75 meshes to 1 inch. In the table, this material is given as coarse screenings. Forty-eight per cent of volume was voids. For determining the effect of the use of the

screenings containing dust, several concrete blocks were made with screenings herein called fine screenings, 39 per cent of which passed through a sieve with meshes 20 to 1 inch and 16 per cent through 75 to 1 inch. It contained 31 per cent voids.

The Louisville cement was fresh and sound. The 24-hour test of its strength averaged 124 pounds, and the 7-day test 125 pounds. The Portland cement was slow setting, the 24-hour test averaging 33 pounds, but the 7-day test showed high strength, averaging 382 pounds.

In the mixture of ½ coarse screenings and 1 stone, 28 per cent of the volume was voids, while in the mixture of ½ sand and 1 stone about 20 per cent was voids. The commonly used proportions of 1 Louisville cement, 2 sand or screenings and 5 stone by volume, and also 1 Portland cement, 3 sand or screenings, and 6 stone were chosen, in order to make conditions similar to those ordinarily used in construction. Care was taken to mix the materials thoroughly.

The concrete was formed in molds making cubes or blocks with six inches for each dimension. The materials were thoroughly tamped, and care was taken to distribute the stone evenly and also to place a facing of mortar at the top and bottom of the cube. These concrete blocks were removed from the mold as soon as they became sufficiently hard, and for the first few days were kept dampened with a covering of wet cloths, and for the remainder of the time these cloths were occasionally wet. The concrete was at no time immersed in water, as it was thought best to make the conditions similar to those of pavement and above ground constructions.

At the end of two weeks for the short-time tests and of two months for the long-time tests, the concrete cubes were crushed in a Riehle testing machine. To facilitate the even distribution of the load, a layer of fine molder's sand about $\frac{1}{16}$ inch thick was placed below the cube and another above it and power was applied through a spherical compression block. The results of the tests are as nearly uniform as may be expected from materials made up under such chances for variation.

CONCLUSIONS.

The strengths of the different concretes are tabulated in Table XVII. and are also shown in detail on the sheets accompanying this report. They may be summed up as follows:

In general, the strength of the concrete made with screenings and broken stone is greater than that of concrete made with sand and broken stone. This is true both of long- and short-time tests, with Louisville and Portland cement concrete. The excess of strength in the screenings concrete is 18 per cent with the Louisville long-time test and 12 per cent with the Portland long-time test. It is safe to say that with the same mixture of materials as here used, the screenings concrete is from 10 to 20 per cent stronger than the sand concrete.

Concrete beams, 6x6x22 inches were also made, and the results showed in the same way the superior strength of the coarse screenings over sand.

The results with the screenings containing dust were not so favorable to the use of screenings, the fine screenings concrete being materially weaker than the sand concrete.

A mixture of fine sand, coarse screenings and stone was tried which gave 57 per cent more strength than the sand concrete, and 40 per cent more than the screenings concrete. It was composed of 1 part Portland cement, 1 part fine sand which had passed through a sieve having 20 meshes to 1 inch, 3 parts coarse screenings, and 6 parts broken stone. This concrete was in every way superior to the others.

The results of the tests seem to indicate that for such concrete the substitution of coarse limestone screenings, free from dust, for sand gives a stronger and better concrete.

Respectfully submitted,
ARTHUR N. TALBOT.

TABLE XV.

MECHANICAL ANALYSIS OF MATERIALS.

Diam. of Ring or Number of Meshes per inch of Sieve.	Per cent. of Total Rejected. Broken Stone.	Coarse Screenings.	Fine Screenings.	Sand.	Louisville Cement	Portland Cement.
1½" Ring	....	....	....	....	....	....
1¼"	27.8	....	....	....	....	....
1"	74.2	....	....	....	....	....
¾"	98.5	....	....	....	....	....
½"	100.0	....	....	....	....	....
No. 4 Sieve	....	6.5	3.2	9.5	....	....
8	....	49.6	15.3	22.4	....	....
20	....	94.5	60.9	48.9	....	....
50	....	96.8	79.9	68.0	13	0.2
75	....	97.8	84.0	90.4	22.5	2.2
100	....	....	....	....	27.0	6.7

TABLE XVI.

TENSILE STRENGTH OF CEMENT.

Kind.	Age.	Tensile Strength* per Square Inch.
Louisville	1 Day	124 Lbs.
	7 Days	125 "
Portland	1 Day	33 "
	7 Days	350 "

* Average of 5 Briquettes.

TABLE XVII.

COMPRESSION TESTS OF CONCRETE.

	Louisville Cement. Proportions.	Strength of 6-in. cube. Age 15 Days.	Strength of 6-in. cube. Age 2 Months.	Portland Cement. Proportions.	Strength of 6-in. cube. Age 15 Days.	Strength of 6-in. Cube. Age 2 months.
SAND CEMENT.	Cement 1, Sand 2, Broken-Stone 5.	9900	16000	Cement 1, Sand 3, Broken-Stone 6.	42,000	42700
		9300	16700		49,000	47000
		10500	19400		41,600	45000
		......	10600		......	43200
		......	11000		......	37200
		......	11800		......	47000
	Average	9900	14250		44200	43680
COARSE SCREENINGS CEMENT.	Cement 1, Coarse Screenings 2, Broken-Stone 5.	15900	12500	Cement 1, Coarse Screenings 3, Broken-Stone 6.	46500	39000
		14000	14400		49000	49000
		13500	12000		40000	49500
		......	21600		......	60800
		......	19500		......	47000
		......	20500		......	49500
	Average.	14470	16750		45170	49130
SAND AND COARSE SCREENINGS CONCRETE.			Cement 1, Sand 1, Coarse Screenings 3, Broken-Stone 6.			61600
						72000
						71700
	Average.					68430

Report of Test of Concrete Beams made for Artesian Stone and Lime Works Co.

TEST OF TRANSVERSE STRENGTH.

Lab. No.	Breadth	Depth	Length of Span	Breaking Load	Modulus of Rupture 3/2 We/bd2	Proportions
1077	6″	6″	18″	3700	462	Port. Cement, 1. Coarse Scr'gs, 3. Broken-Stone, 6.
1078	"	"	"	4200	525	
1079	"	"	"	3450	431	Port. Cement, 1. Fine Scr'gs, 3. Broken-Stone, 6.
1080	"	"	"	2100	282	Port. Cement, 1. Sand, 3. Broken-Stone, 6.
1081	"	"	"	2400	300	

Correct: PAUL CHIPMAN.

Urbana, Ill., Mar. 1, 1897.

Report of test made for Artesian Stone and Lime Works Co.

Material: Concrete, Portland, Sand.

Character of test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Str. per sq. in.	Age.	Proportions.
1074	6x6x6"	42000	1167	15 Days	Portland Cement 1
1075	"	49000	1361	"	Sand 3
1076	"	41600	1155	"	Broken Stone 6
Average		44200	1228		

Correct, PAUL CHIPMAN.
Date, Mar. 1, 1897.

Report of Test made for Artesian Stone and Lime Works Co.
Material: Concrete, Portland, Coarse Screenings.
Character of Test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Strength per sq. in.	Age.	Proportions.
1071	6x6x6"	46500	1292	15 days	Portland Cement 1
1072	"	49000	1361	"	Coarse Screen'gs 3
1073	"	40000	1111	"	Broken-Stone 6
Average,		45170	1255		

Correct: PAUL CHIPMAN.
Date, Mar. 1, 1897.

Report of test made for Artesian Stone and Lime Works Co.
Material: Concrete, Louisville, Fine Screenings.
Character of test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Str. per sq. in.	Age.	Proportions.
1068	6x6x6"	4600	128	15 Days	Louisville Cement 1
1069	"	4100	114	"	Fine Screenings 2
1070	"	4200	117	"	Broken Stone 5
Average		4300	120		

Correct, PAUL CHIPMAN.
Date, Mar. 1, 1897.

Report of Test made for Artesian Stone and Lime Works Co.
Material: Concrete, Louisville, Coarse Screenings.
Character of Test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Strength per sq. in.	Age.	Proportions.
1062	6x6x6"	15900	442	15 days	Louisville Cement 1
1063	"	14000	389	"	Coarse Screenings 2
1064	"	13500	375	"	Broken-Stone 5
Average,		14470	402		

Correct: PAUL CHIPMAN.
Date, Mar. 1, 1897.

Report of test made for Artesian Stone and Lime Works Co.
Material: Concrete, Louisville, Sand.
Character of test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Str. per sq. in.	Age.	Proportions.
1065	6x6x6"	9900	275	15 Days	Louisville Cement 1
1066	"	9300	258	"	Sand 2
1067	"	10500	292	"	Broken Stone 5
Average		9900	275	"	

Correct, PAUL CHIPMAN.
Date, Mar. 1, 1897.

Report of Test made for Artesian Stone and Lime Works Co.
Material: Concrete, Portland, Sand—Coarse Screenings.
Character of Test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Strength per sq. in.	Age.	Proportions.	
1053	6x6x6"	61600	1711	2 mos.	Portland Cement	1
1054	"	72000	2000	"	Sand (Screened)	1
1055	"	71700	1992	"	Coarse Screenings	3
					Broken-Stone	6
Average,		68430	1901			

Correct: PAUL CHIPMAN.
Date, Mar. 1, 1897.

Report of test made for Artesian Stone and Lime Works Co.
Material: Concrete, Louisville, Coarse Screenings.
Character of test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Str. per sq. in.	Age.	Proportions.
1056	6x6x6"	12500	347	2 Months	Louisville Cement 1
1057	"	14400	400	"	Coarse Screenings 2
1058	"	12000	333	"	Broken Stone 5
1059	"	21600	600	"	
1060	"	19500	541	"	
1061	"	20500	570	"	
Average		16750	456		

Correct, PAUL CHIPMAN.
Date, Mar. 1, 1897.

Report of Test made for Artesian Stone and Lime Works Co.
Material: Concrete, Louisville, Fine Screenings.

Character of Test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Str. per sq. in.	Age.	Proportions.
1047	6x6x6"	9000	250	2 Months.	Louisville Cement 1.
1048	"	10500	292	"	Fine Screenings 2.
1049	"	6000	167	"	Broken-Stone 5.
1050	"	10100	280	"	
1051	"	6000	167	"	
1052	"	12500	347	"	
Average,		9020	251		

Correct. PAUL CHIPMAN.

Date, Mar. 1, 1897.

Report of Test made for Artesian Stone and Lime Works Co.

Material: Concrete, Portland, Sand.

Character of Test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Strength per sq. in.	Age.	Proportions.
1041	6x6x6"	42700	1186	2 months.	Portland Cement 1
1042	"	47000	1305	"	Sand . . 3
1043	"	45000	1250	"	Broken-Stone 6
1044	"	43200	1200	"	
1045	"	37200	1033	"	
1046	"	47000	1305	"	
Average,		43680	1213		

Correct: PAUL CHIPMAN.

Date, Mar. 1, 1879.

Report of Test made for Artesian Stone and Lime Works Co.

Material: Concrete.

Character of Test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Str. per sq. in.	Age.	Proportions.
1035	6x6x6"	39000	1083	2 Months.	Portland Cement 1.
1036	"	49000	1361	"	Coarse Screenings 3.
1037	"	49500	1375	"	Broken-Stone 6.
1038	"	60800	1689	"	
1039	"	47000	1305	"	
1040	"	49500	1375	"	
Average		49130	1365	"	

Correct. PAUL CHIPMAN.

Date, Mar. 1, 1897.

LABORATORY OF APPLIED MECHANICS.

UNIVERSITY OF ILLINOIS.

Report of test made for Artesian Stone and Lime Works Co.

Material: Concrete, Louisville, Sand.

Character of test: Compression.

Lab. No.	Dimensions.	Ultimate Strength.	Ultimate Strength per sq.in.	Age.	Proportions.	
1029	6x6x6"	16000	444	2 mos.	Louisville Cement	1
1030	"	16700	464	"	Sand . .	2
1031	"	19400	539	"	Broken-Stone	5
1032	"	10600	294	"		
1033	"	11000	306	"		
1034	"	11800	328	"		
	Average,	14250	396			

Correct: PAUL CHIPMAN.

Date, Mar. 1, 1897.

DISCUSSION.

Written discussion by ALFRED NOBLE, Mem. W. S. E.

The results given in this paper show those wide variations that might be expected in crushing tests of concrete samples so small as 6-inch cubes. An accidental juxtaposition of a few pieces of broken stone might easily give a result much higher than that due to the actual strength of concrete.

Referring to the cement used, the Louisville cement shows an increase of tensile strength of less than 1 per cent between the ages of 1 and 7 days. This is less than the average rate of increase in strength of Louisville cement, but the writer has occasionally obtained like results with this cement and would not by any means conclude that the sample was abnormal or that it would fail to show a satisfactory rate of development at longer periods. He is unable, however, to agree that Portland cement of 350 lbs. tensile strength at 7 days, neat, is of high strength. At this age a strength of 500 lbs. per sq. inch is more nearly normal when the tests are made carefully by the usual method.

As to the tests themselves, the results as shown in table XVII are erratic, as should be expected from the nature of the case; they would have appeared still more so if the tests of concrete with Louisville cement and fine screenings had been included in the table. The Test Reports which follow the table give these figures; they indicate a much lower strength at 15 days than concrete with coarse screenings; a less unfavorable comparative result at 2 months and suggest the possibility that concrete with fine screenings may eventually correspond closely in strength with the other.

In connection with the compressive tests of these concretes it is interesting to note the results of transverse tests given in the

paper. These give for concrete with fine screenings much greater strength than with sand and not greatly less than those with coarse screenings. These apparently contradictory results of compressive and transverse tests do not appear to the writer as necessarily inconsistent; the concrete with the fine screenings, although apparently deficient in compressive strength, may have had a good degree of tensile strength, and as the break in transverse tests was probably on the tension side, the tensile strength determined its resistance. A natural cement tested by the writer several years since gave very good tensile strength, but was quite deficient in hardness and the broken briquettes were easily rubbed into fragments; this cement was probably deficient in compressive strength. The mortar with fine screenings, referred to in the paper, containing a large proportion of limestone powder, may have had somewhat like properties.

The writer would object to the term "long-time," as applied to tests of mortar or concrete at the age of 2 months. A long-time test should be one which indicates the behavior of the product for a long time, and the principal defect of these tests is that they do not show this. The concrete described in this paper is to quite an extent a new product; a large proportion of material is introduced which will give aggregations, and, probably, chemical reactions quite different from those given when silicious sand is used, and the excellence and permanence of the product cannot be assured without experiments or experience covering a much longer period. The author of the paper appears to have had some such conclusion in mind in making his final statement here quoted:

"The results of the tests *seem to indicate** that for such concrete the substitution of limestone screenings, free from dust, for sand gives a stronger and better concrete."

This is a judicious summing of the experiments given in the paper. The results of these tests are indications rather than a demonstration, and need extension both in number and time. A series of tensile tests made at the Memphis Bridge† are perhaps of sufficient pertinence to warrant the insertion here of a summary of the results. The number of the tests, 2,400, was too large to permit entering here a detailed record.

The cements used were normal samples of the several brands. The sand was dredged from the Mississippi River and was clean and sharp; it was screened, and only that passing through a No. 20 sieve and retained on a No. 30 was used. The limestone screenings were from hard limestone found in Eastern Arkansas about 60 miles northwest of Memphis.

For determining proportions, the net weight of a barrel of cement of each of the brands used was compared with the weight of equal volumes of dry sand and dry screenings, compacting as

*Italics by the present writer.

†Mr. Geo. S. Morison, M. W. S. E., Chief Engineer.

much as possible by shaking and jarring the measure. From these weighings it was found that 4 oz. of Louisville cement equaled in volume 6 oz. of sand or 6 oz. of limestone screenings and that 5 oz. of Portland cement equaled in volume 5¼ oz. of sand or 5¼ oz. of limestone screenings; in making the briquettes the amounts for each briquette were weighed out on this basis.

TABLE XVIII.

Comparative tensile strength of cement mortars containing sand and mortars containing instead of sand like proportions of limestone screenings.

A=screenings passing No. 20 sieve, including dust.

B=screenings passing No. 6 sieve, including dust.

B differs from A only in including fragments passing No. 6 sieve and retained on No. 20 sieve.

Proportions by volume.

Comparisons by percentages.

Each result the mean of ten tests.

No. of Series.	Composition of Mortar.	Age of Briquettes when broken.	Kind of Cement. Relative Strength in per cent.		
			Louisville (Natural).	Alsen's (Portland)	Dyckerhoff (Portland).
1	1 cem: 1 sand		100	100	100
	1 cem: 1 A	28 days	102	104	126
	"	6 mos.	150	95	116
	"	1 year	164		121
2	1 cem: 2 sand		100	100	100
	1 cem: 2 A	28 days	131	108	104
	"	6 mos.	152	103	119
	"	1 year	235		139
	1 cem: 2 B	28 days	133	164	135
	"	6 mos.	185	154	144
	"	1 year	181		175
3	1 cem: 1 A		100	100	100
	1 cem: 1 B	28 days	97	121	119
	" "	6 mos.	103	123	109
	" "	1 year	103		117
4	1 cem: 2 A		100	100	100
	1 cem: 2 B	28 days	98	148	128
	" "	6 mos.	103	134	124
	" "	1 year	105		123

INDICATIONS FROM FOREGOING TABLE XVIII.

From Series 1.

The substitution of fine screenings for sand in 1 to 1 mortars gives stronger mortars, the results in this series being as follows:

1st. With Louisville cement, an increase of 2% at the age of 28 days; 50% at the age of 6 months, and 64% at the age of 1 year.

2nd. With Alsen's cement, an increase of 4% at the age of 28 days and a decrease of 5% at the age of 6 months.

3rd. With Dyckerhoff cement, an increase of 26% at the age of 28 days; 16% at the age of 6 months, and 21% at the age of 1 year.

The numerical ratios would certainly be found different if the tests were duplicated, but it might be expected that the general indication would be the same, viz.: The substitution of fine limestone screenings for sand in 1: 1 mortars gives a stronger mortar.

From Series 2.

The substitution of limestone screenings for sand in 1: 2 mortars gives decidedly stronger mortars, the coarser screenings giving better results than the finer.

From Series 3 and 4.

The superiority of the coarse screenings indicated in Series 2 is confirmed; the difference is not important with Louisville cement, is material with Dyckerhoff and is large with Alsen's. Attention is invited to the apparent difference of behavior of the two Portland cements.

The tests summarized in the next table were made to obtain an indication of the effect on mortars of cement and sand of adding limestone screenings in specified proportions; one effect would be to increase the quantity of mortar for a given volume of cement, and in most cases to decrease the cost of the mortar per unit of volume.

TABLE XIX.

Effect produced on the tensile strength of mortars of cement and sand by adding specified proportions of limestone screenings.

A=screenings passing No. 20 sieve, including dust.

B=screenings passing No. 6 sieve, including dust.

B differs from A only in including fragments passing No. 6 sieve and retained on No. 20.

Proportions by volume.

Comparisions by percentages.

Each result the mean of ten tests.

No. of Series.	Composition of Mortar.	Age of Briquettes when broken.	Kind of Cement. Louisville (Natural).	Alsen's (Portland).	Dyckerhoff (Portland).
			Relative Strength in per cent.		
5	1 cem: 1 sand		100	100	100
	1 cem: 1 s'nd: ½A	28 days	91	98	108
	"	6 mos.	121	90	105
	"	1 year	141		104
	1 cem: 1 s'nd: ½B	28 days	99	94	99
	"	6 mos.	132	90	98
	"	1 year	137		111
	1 cem: 1 s'nd: 1A	28 days	82	91	96
	"	6 mos.	132	90	102
	"	1 year	154		106
	1 cem: 1 s'nd: 1B	28 days	75	95	105
	"	6 mos.	166	92	103
	"	1 year	158		107
6	1 cem: 2 sand		100	100	100
	1 cem: 2 s'nd: ¼A	28 days	117	109	101
	"	6 mos.	112	101	98
	"	1 year	124		119
	1 cem: 2 s'nd: ½A	28 days	108	110	94
	"	6 mos.	137	107	95
	"	1 year	122		116
	1 cem: 2 s'nd: ¾A	28 days	68	101	96
	"	6 mos.	136	98	96
	"	1 year	132		116
	1 cem: 2 s'nd: 1A	28 days	101	94	104
	"	6 mos.	135	92	93
	"	1 year	126		114
	1 cem: 2 s'nd: ¼B	28 days	92	106	102
	"	6 mos.	110	103	96
	"	1 year	119		105
	1 cem: 2 s'nd: ½B	28 days	84	109	101
	"	6 mos.	113	105	96
	"	1 year	122		103
	1 cem: 2 s'nd: ¾B	28 days	63	111	95
	"	6 mos.	122	105	90
	"	1 year	143		110
	1 cem: 2 s'nd: 1B	28 days	43	99	96
	"	6 mos.	112	97	91
	"	1 year	132		107

INDICATIONS FROM THE FOREGOING TABLE, XIX.

1st. The addition of limestone screenings to mortar of 1 Louisville cement: 1 sand even up to the proportion of 1 screenings increases the strength of the mortar, but retards for 28 days or more the development of its strength. If the mortar contains equal volumes of Portland cement and sand, the addition of limestone screenings to the limit above named affects the strength of the mortar very slightly. As between Alsen's and Dyckerhoff cements, the mortars with Alsen's cement appear to be slightly reduced in strength by the addition of screenings, while mortars with Dyckerhoff cement appear to be slightly increased in strength. No appreciable difference in result is given by the two grades of screenings used in the tests.

2nd. The addition of screenings to mortars of 1 cement: 2 sand gives variations in strength corresponding closely with those noted in the preceding paragraph,

It is to be noted that there is no apparent deterioration of the mortars containing limestone screenings up to one year; but, on the contrary, the ratio of superiority increases.

Reference may be made here to a series of tests carried out at the St. Marys Falls Canal, Mich., and recorded in the Report of the Chief of Engineers, U. S. Army, for 1896. This series shows the strength of mortars containing cement and sand only compared with mortars containing in addition to the same ingredients a small amount of limestone screenings or other adulterants. The general result of adding the screenings was an increase in strength at all ages up to 1 year and no deterioration. These mortars contained 1 part by weight of cement to 4 parts of sand, to which was added for the comparison ¼ part of limestone screenings.

The results of all these tests point in one direction and corroborate the conclusions of the author of the paper. It must be remembered, however, that these are test-room results, and that the conditions of actual work in the open air are different. In the test-room the materials are dry and the thorough incorporation of the cement with sand or screenings is easy, but in actual construction the sand and screenings are moist and sometimes saturated. In order to secure a thorough mixture of these materials, unusual care must be taken or a product comparable with that made in the test-room will not be obtained.

The writer does not clearly understand the meaning of the author of the paper in referring to the sand used in these experiments as "of a quality better than is used on public work." In the district along the great rivers of the Mississippi Valley and along the North Atlantic coast, which have to some extent fallen under the writer's observation, sand is obtained and ordinarily used which is siliceous, clean, sharp, sufficiently coarse, and in general is not much inferior to the crushed quartz furnished for the test-room. As the great public works are usually near the great water courses or near the seashore, the author's

phraseology seems rather sweeping, although possibly quite accurate.

The publication of the tests recorded in the paper is commendable as an important link in a chain of evidence which, when completed, may lead to considerable economy in the making of concrete or improvement in its quality. The writer would also express high appreciation of the table giving the mechanical analysis of the materials. It is definite and valuable information of a kind not often found on record.

Mr. Boardman: I would like to ask Mr. Noble's opinion of the cause of the greater strength of the mortar composed of cement, sand and screenings than of that composed of cement and screenings, as shown in the paper of the evening. In his own tests, as I understood them, those with a concrete of cement, sand and screenings were not much stronger, if any, than for a concrete of cement and screenings without sand.

Mr. Noble: I got better results with the Portland cement with unmixed screenings, but, then, it is to be remembered that when screenings were added to sand mortar it was a further adulteration of the mortar. The addition of the limestone screenings to a given mortar of cement and sand appeared to increase its strength.

Mr. Yoder: I have here specimens of stone taken from some that has been delivered for concrete on the work now being done on Jackson Street Boulevard for the South Park Commissioners. I would like members present who are interested to examine them and give their opinions. Some of the stone has been rejected because of a great deal of fine dust coating the stones. Prof. Talbot seems to make a point that screenings should be free from fine dust. Our concrete is mixed by hand, and it was noticed in mixing the stone coated with the fine dust with the mortar that it was almost impossible to get it thoroughly coated and the mortar in close contact with each particle of stone. There are in some of this stone particles coated with an oily substance like petroleum or bitumen or something of the kind. That stone has been objected to also on this account, and I would like very much if any member of the society present that has had experience with this kind of stone used in concrete would give me light on the subject.

Mr. Boardman: I remember of making some tests last year of two kinds of limestone. One was clean white stone and the other had a black oily appearance in spots. We crushed some of both kinds and made briquettes of one part Empire Portland cement to two parts crushed stone, I believe. We only crushed enough for very few tests, but the average test with that black stone was, I think, only from half to two-thirds the strength of that with the clean stone.

The Chair.: I remember the test to which Mr. Boardman re-

fers, and the conclusion we came to was that the presence of this oily or bituminous matter very seriously affected the strength of the briquettes, which I think was quite in accordance with the general experience of oily substances in connection with cement.

Mr. Yoder: This oily stone is furnished by the Artesian Stone Co., the same company that Prof. Talbot refers to in his reports of experiments. But I understand that it is also found in the quarry of the Rice Stone Co.

The Chair: They don't claim that feature as being a merit in the stone, do they?

Mr. Yoder: Well, Mr. O'Connell, Sr., of the Artesian Co. said that it is being used all over the city for concrete in foundations for our large buildings, the Fair building was one mentioned, and that it had never been objected to on account of the oily particles. Mr. J. S. Paterson, an old and experienced masonry contractor, said that he had removed some foundations for an elevated road in this city and that the concrete containing this oily stone was very poor.

The Chair: I think I would rather have the common everyday stone.

Mr. Dickinson: I don't think that a great deal of that oily stone is supplied in this town.

The Chair: That is my impression.

Mr. Dickinson: I have seen a great deal of this oily stone, but in Chicago they use very little, if any, of it.

Mr. Koelling: Mr. Reynolds had the kindness to come up to our office and tell us that there was to be a discussion about limestone screenings. Our Mr. J. C. O'Connell, who is an expert in that matter, could not be reached today, and so I came here tonight in order to listen to the paper which Mr. Noble had to offer on the subject. I am glad to have availed myself of the opportunity. It has given me great satisfaction to note that Mr. Noble's numerous tests not only corroborate, but also give additional proof to Prof. Talbot's experience of the superiority of limestone screenings over sand in the mixing of concrete.

About Mr. Yoder's remarks, I wish to say that there seems to be very little known about the black stone in the city of Chicago. We find that some people take it in preference to the white stone, while others favor the latter. The uninitiated, of course, is inclined to prefer the white, because he does not see the black stone very often. Some of the gentlemen present will have noticed the beautiful residence of Mr. J. V. Farwell on the Lake Shore drive and the handsome office buildings of the South Park Commissioners where the black stone shows itself to great advantage. I do not think that anybody can say anything against the much discussed black stone. However, if there is any gentleman present who by actual experience can prove that it is not as good as the white stone, I will be pleased to hear from him.

Mr. Dickinson: Would you favor it for concrete, that is the question?

Mr. Koelling: That is a question I am not prepared to answer. I am not a man who makes concrete, I am a man who sells the stone, and if a man comes in our office and wants to buy the stone we show him our samples. Some people are particular in having the black stone. Some are particular in getting white stone, and some don't care at all.

I believe that if we had quarried black instead of white stone from the beginning and would now send it with a small sprinkling of white stone, the stone would be condemned on account of the white stone. To us it does not make any difference, we would just as soon send the white stone as the black stone.

Mr. Yoder: I am sure, Mr. President, that we would much prefer the white stone in our work on Jackson street.

Mr. Koelling: We are endeavoring to send all the white stone to whomsoever demands it.

Mr. Yoder: I have not examined the last stone sent to our work.

Mr. Koelling: Before we requested Mr. Talbot to make the tests, we learned from a number of our customers that they used limestone screenings instead of sand in the mixture of concrete. Our Mr. O'Connell's personal tests had brought to light these two facts that concrete made with screenings was:

(1) Stronger.

(2) Cheaper.

Mr. Moody being consulted about the matter referred us to Prof. Talbot, whose encouraging letter and tests were read to you tonight. These tests have been rather short and few in comparison with Mr. Noble's, whose valuable, numerous and practical tests, covering more than a year, make it appear much clearer to us that there is no doubt about the superiority of limestone screenings including dust over the sand used heretofore.

Mr. Yoder: We have had considerable trouble with the dust. That is just one of the points, and the stone company's men say the presence of so much dust in the stone and coating the stone is caused by the recent wet weather and in screening it, the dust cannot be separated from the stone. Our specifications for this work do not call for screenings but for clean stone, and we have got to carry out the requirements of the specifications.

Mr. Koelling: However, Mr. Noble's tests have been made with screenings including dust, and I have no doubt that before long we shall see in the specifications of all future improvements, whether public or private, the limestone screenings added, wherever concrete work is desired.

Mr. Dickinson: May I be allowed to say a word?

The Chairman: Yes, we will be very glad to hear from you.

Mr. Dickinson: I have seen a photograph from Professor Simms from the Iowa College of Iowa City, Professor of Engi-

neering. The photograph has been enlarged, I think, about a thousand times. The appearance of the picture represented the formation of ice crystals. Now, of course, it is known to most every one present what the setting of cement is, that is, the crystallization, but right in this connection it seems while of course I have nothing to prove to the contrary that common sense would show to most all of us that these crystals cannot attack and join themselves intimately and solidly to any such substance as is on the outside of this oily stone. I think that is a fair suspicion. He is going to make quite a number of other experiments in a week or two.

The Chair: The photographs must be very interesting indeed as throwing some light as to what takes place in cement as the process goes on.

Mr. Penny: All I would like to ask about is the disintegration of the lime in the stone, whether time tests were made to show that it would last as long as the sand.

Mr. Noble: The tests reported in my written discussion showed a greater relative increase in screenings mortar than with sand mortar; that is to say that the showing is more favorable to screenings in a year than it is in six months. Now, these tests are not a positive demonstration perhaps, yet they point very strongly to the permanence of that superiority. I don't know but it might interest the Society if I should say how I came to make these tests of screenings. I was called upon to settle a dispute between an engineer and contractor as to the amount of fine dust in concrete stone furnished for the jetties at the mouth of the Mississippi, and after having done that I became interested in the question as to what harm the screenings would do if left in the stone. I made these tests with that point in view, and became well satisfied that if the mixing was exceedingly thorough the amount of dust in screenings as ordinarily found in concrete stone would not be in any way injurious to the concrete. It seemed to me the mixing ought to be so thorough that the mortar would get in contact with every stone. Now there are one or two samples of stone here that have so much dust attached to them that I should doubt the possibility of securing such contact by ordinary hand mixing, but if mixed in a suitable machine I have no doubt that the mortar would be in contact with the stone and that the dust screenings would do no harm.

The Chair: Some points have arisen in the course of discussion that may be of some interest. With regard to this oily stone, we have made some experiments in the laboratory of the sanitary district, as described by Mr. Boardman, which indicated that the stone containing the black material was not suitable material to mix in cements, at any rate they give a less strength than if the black substances had been absent. In the same connection I may mention the use of sands containing lignite, which is a vegetable matter, abounding in the sands of

the Mississippi river, and unless it is washed out the sands are unfit entirely to use with cement. Immediately in the vicinity of any lignitic particle, the cement seems to be destroyed perhaps for a diameter of an eighth of an inch, a phenomenon of the same kind that might be expected with the use of oily substances.

Now with regard to the general question as to the action of limestone in cements, whether it be in the form of screenings or be finely ground, I will refer to a series of experiments that have been made in the sanitary district laboratory and experiments that are now being carried on there. Instead of using limestone we have used iron slag pulverized, which is very high in lime, not in the same form that it is found in limestone, but containing enough lime to characterize it as a lime compound. The addition of the pulverized slag ground as finely as cement dust has a very radical influence on the cement, a mixture of one part of pulverized slag to one part of the cement giving a strength in seven to twenty-eight days much stronger than would be obtained by using the neat cement alone. Perhaps Mr. Boardman has those figures in his mind. I think he made those tests.

Mr. Boardman: I have not the exact figures, but I know that there was a marked increase of, I think, 50 or 60 per cent over the strength of the neat cement for ages up to one or two months.

The Chair: That is using simply slag sand and not the pulverized slag.

Mr. Boardman: Yes, but the finer ground slag, as I remember it from those earlier tests, was much slower in developing its strength, though in six months or a year mixtures of this finely ground slag with cement greatly surpassed the pure cement in strength. But the later tests that you have carried on in this line since I left were more extensive.

The Chair: The later tests showed that pulverized slag has the effect of very radically increasing the strength of the mixture over and above that of the constituent parts, indicating the chemical action in process the same as may take place by the admixture of limestone screenings with cement. The experiments which are now being made cover quite a wide range, and tests running through two years have been instituted with the neat cement mixed with 10, 25, 50, 100 and 200 per cent of the pulverized slag. These mixtures have been taken as cements to mix with ordinary building sand in proportion of two to one and three to one, each test running for two years. The briquettes that have been broken verify further the results obtained from a 100 per cent and a 200 per cent mixture of Louisville cement and pulverized slag, made something over a year ago, now perhaps eighteen months ago,which showed results about as follows: Taking the mixtures of the Louisville cement and the slag alone, the hardening was very slow, and very little strength was obtained up to certainly three months, and not very strong at the end of six

months. At the end of a year the strength reached that of Portland cements. The same is also true of the mixtures of common building sand with the adulterated cement, the three to one mixture of adulterated cement and sand giving strength in a year equal to what would be obtained with a three to one mixture with a good quality of Portland cement with sand.

Written discussion by S. M. Rowe, Mem. W. S. E.

Hoping to add somewhat to the valuable data given by Mr. Talbot in his interesting paper in relation to the value of crushed rock screenings, I will submit some notes obtained while acting as inspector for the public works of Chicago.

These are given in the form that the notes were compiled at the time the investigations were made, having since had no time or opportunity to revise. Mistakes and inaccuracies may have crept in, but not to such extent as to be essential, the general trend being evident.

I have long advocated the use of crusher run stone, believing in consequence of the greater degree of compactness secured, and the reduction of the percentage of voids to be filled by the mortar, that stronger work will be secured.

The crushed rock in general use in Chicago, and which was used in my investigations, is a very fine grained compact limestone, much of it slightly impregnated with crude petroleum and weighing near 160 lbs. per cubic foot before crushed. As it comes from the crusher from 25 to 30 per cent will be so finely pulverized as to pass a screen with ¼-inch mesh, while the coarser portion up to 2-inch will form 70 to 75 per cent of the whole in weight. I have found that any assorted grade will have 50 per cent of voids, while if all the grades above quarter inch are used the percentage of voids will be 35 per cent, or even lower. My table XXI gives the amount of each grade as derived from the analysis of two half-yard lots, and is probably as good an estimate as can be made, or near enough for practical purposes.

It would be impracticable to use the screenings in any case without first separating from the coarser product, and if so used, would be as a substitute for sand, and combined with cement into mortar before adding the stone, as with any concrete. Neither would the 30 per cent of screenings be sufficient to form the mortar necessary to solidify the mass so that an additional allowance of screenings or of sand would be necessary. It has been my impression that mortar from 30 to 50 per cent in excess of the determined voids of the stone is necessary for good concrete.

As sand has been the standard material for the purpose for which it is proposed to substitute the screenings, I have in my investigations used it as a basis of comparison. I have here in table XXII a case of assorted sands combined with Giant Portland cement in the proportion of one of cement and two (approxi-

Crushed Rock. Physical characteristics "E"

—Granite. From S K Wheelock, Chf Eng, Bureau of Streets. —S 4 wh —

		Dry by volume.			As a solid						I.
Grade	Size of mesh	Weight oz per Cu. inch	Weight, lbs per Cu, ft,	Weight. lbs per Cyd	Weight. oz per Cu, inch	Weight lbs per Cu foot	Weight, lbs per Cyd.	Per ct, Voids	Total Wt of each grade, oz	Per, ct of the whole	
D	1" to 1/2"	.7932	85.67	2313.	1.5242	164.61	4445.	47.84	476.00	83.47.	
E	1/2" to 1/4"	7797	84.21	2274	1 5204	164.20	4433.	48.72	94.24	16 53	
DE*	1" to 1/4"	.8469	91.47	2470.	1.5079	162.85	4397.	43 84	570.24	100 00	

* D. and E are the Coarse grad and FG 2/6 are the screenings passing the quarter inch mesh.
— Granite — — FG 2/6 —

F	1/4" to 1/8"	.7575	81.84	2210.	1 4324	154.70	4177.	47.09	207.12	34.16	II.
G²	1/8" to 1/16"	.7719	83.36	2251.	1.3679	147.73	3988.	43.58	127.94	21.09	
G³	1/16" to 1/30"	.7578	81.84	2210.	1.2815	138.40	3737.	40.87	75.12	12 38	
G⁴	1/30" to 1/50"	.7771	83.93	2266.	1 2547	135.60	3658.	38.06	67.92	11 20	
G⁵	1/50" to 1/100"	.8016	86.57	2337.	1.2630	136.40	3683.	36.54	57.25	9.43	
G⁶	pass 1/100"	.8437	91 12	2460.	1 4016	151 37	4187.	39.78	71.25	11.74	
FG 2/6	1/8" to + 1/100"	1.0474	113 12	3054	1 4130	152.60	4119.	25.87	606 60	100.00	

TABLE XX.

CRUSHED LIMESTONE.**—CRUSHER RUN.--PHYSICAL CHARACTERISTICS.

Grade.	Size of Mesh.	Dry by Volume. Weight oz. per Cu. Inch.	Dry by Volume. Weight lbs. per Cu. ft.	Dry by Volume. Weight lbs. per Cyd.	As a Solid. Weight oz. per Cu. Inch.	As a Solid. Weight lbs. per Cu. ft.	As a Solid. Weight lbs. per Cyd.	Per ct. Voids,	Total Wt. of each grade, ozs.	Per ct. of the Whole.	I.
A.	Above 2"							50.00	536.00	3.75	III.
B.	2" to 1½"	.7490	80.89	2184.	1.5896	171.68	4635.	51.70	868.00	6.08	
C.	1½" to 1"	.7931	85.66	2312.	1.5070	162.76	4394.	47.45	2436.00	17.09	
D.	1" to ½"	.8226	88.83	2398.	1.5406	166.38	4492.	46.61	3580.00	25.07	
E.	½" to ¼"	.8029	86.71	2341.	1.6285	166.08	4457.	47.47	2380.00	16.60	
F	¼" to ⅛"	.7588	81.95	2213.	1.5175	163.89	4425.	49.69	1428.00	10.00	Per ct. of G.
G^2	⅛" to 1/16"	.8312	96.17	2570.	1.4764	159.45	4304.	43.70	736.05	8.49	35.87
G^3	1/16" to 1/30"	.8288	89.51	2417.	1.3959	150.76	4070.	40.63	451.24	4.42	21.99
G^4	1/30" to 1/50"	.8253	89.13	2407.	1.3919	150.33	4059.	40.71	249.18	2.21	12.14
G^5	1/50" to 1/100"	.8739	94.39	2548.	1.4280	154.22	4164.	38.80	172.91	2.44	8.67
G^6	1/100" +	.8257	89.18	2408.	1.3317	143.82	3883.	38.00?	437.69	3.85	21.33
G^{2}_{6}	⅛" to 1/100" +	1.0368	111.98	3023.	1.4324	164.70	4177.	27.62	2052.00	21.48	100.00
F.G.	¼ to 1/100" +								3480.00	31.41	
G'									2052.00		
								Total.→	13280.00		

** This is a very compact flinty limestone

TABLE XXI.

GIANT AM. PORT CEMENT WITH ASSORTED SANDS "C"

Lab No	Date 1896	Name of Cement	Samp No	Sand	% Vol. of Cement	% Water	No Pieces	Weight Inch oz	Cubic foot lbs	yard lbs	% Voids	4 to 8	8 to 16	16 to 20	20 to 30	30 to 50	50 to 74	74 to 100	+100
141	April 16th	Giant	AGR2	4-8	47.12	9.20	22	.9738	105.2	2840	38.62	100							
142	" "	"	"	8-16	46.67	9.33	22	.9828	106.1	2864	37.34		100						
143	" 11th	"	"	16-20	47.16	9.50	22	.9562	103.3	2789	37.76			100					
144	" "	"	"	20-30	45.39	"	24	.9328	100.7	2720	36.31				100				
145	" 13th	"	"	30-50	45.04	10.00	25	.9434	101.9	2752	36.03					100			
146	" "	"	"	50-74	44.60	10.94	26	.9053	97.77	2640	35.69						100		
147	" 14th	"	"	74-100	46.00	12.50	26	.9000	97.20	2624	36.80							100	
148	" "	"	"	+100	41.57	"	26	.9578	103.5	2793	33.26								100
154	" 15th	Alpha	S2d	Eqld	22.05	10.00	24	1.1359	122.6	3312	22.05	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
155	" "	"	"	Grd	24.41	10.00	27	1.0909	117.8	3181	24.21		21.85	19.33	16.80	14.30	11.76	9.24	6.72
	CRUSHED ROCK SCREENINGS. (passing 1/8" mesh)							Weight Cu" oz.	Cu' lbs.	Cyd lbs.	Voids Comp %	Voids Loose %							
231	Aug 17th	Empire	52sh	G^2	60.00	12.00	64	.8312	89.77	2424	43.70	56.85	<100>						
232	" 18th	"	"	G^3	54.00	13.00	60	.8288	89.51	2417	40.63	63.78		<---	100>				
233	" 19th	"	"	G^4	55.00	15.00	69	.8253	89.13	2406	40.71	59.84				<100>			
234	" 20th	"	"	G^5	52.00	16.00	48	.8739	94.38	2548	38.20	52.12					<---	100>	
235	" 21st	"	"	G^6	50.00	19.00	65	.8257	89.18	2408	43.16								<100>

TABLE XXII.

CEMENT = VOIDS IN SAND + 25%

Laboratory Journal No XVIII. (26) "D"

Lab No	% Absn	Vol. Each Bricket	Weight Per Cu inch ozs.*	Weight Per Cu foot lbs*	Weight Per Cyd lbs.*	4 days	Tensile Strength 7 days	14 days	21 days	28 days	60 d's	90 d's	6 mos	12 mos	18 mos	24 mos
141	9.35	4.06	1.2751	137.7	3718	194	243	387	447	442	498	539	470	665		
142	10.23	4.12	1.2209	131.9	3560	193	269	370	348	345	436	473	512	572		
143	11.69	4.15	1.1199	120.9	3266	156	186	229	241	250	309	313	397	396		
144	12.30	4.24	1.1000	118.7	3206	138	211	283	282	281	322	322	402	440		
145	14.34	4.31	1.0103	109.1	2946	103	149	188	194	205	267	238	275	318		
146	15.36	4.23	1.0107	109.2	2947	94	122	154	162	214	226	260	275	308		
147	16.00	4.22	.9928	107.2	2895	56	98	115	172	153	183	211	208	253		
148	17.88	4.21	1.0266	110.9	2993	57	98	112	139	155	198	161	229	271		
154	9.49	4.21	1.1604	125.3	3384	91	122	162	161	251	281	309	340	354		
155	9.61	4.31	1.1564	124.9	3372	74	116	166	246	272	302	364	384	372		
* Kiln dried.																
	1 day	2 days	3 days	4 days	5 days	6 days										
231	160	326	313	313	344	388	451	490	508	528	619	665	745	778		
232	126	261	323	312	364	348	379	421	447	474	578	633	664	642		
233	68	249	250	264	344	321	333	381	408	475	513	590	638	726		
234	94	214	240	298	298	287	320	326	350	344	411	476	621	584		
235	84	126	154	161	178	191	265	229	261	277	305	407	447	549		

TABLE XXIII.

mately) of sand, tables XXII and XXIII and diagram Fig. 159, also the crushed rock screenings contained in the same tables and in diagram Fig. 160 with Empire cement, but with 15 to 20 per cent greater amount of cement.

For tensile strength we find the mean of eight of the assorted sands equal about 400 lbs., the coarsest being 665 lbs., while the finest is 270. In the same table we find (Nos. 154, 155) two cases where the equalized and the graded sands are used with only about one part of cement to four and four and one-quarter parts of sand respectively gives 360 lbs. tensile strength.

For compressive strength (ultimate), we get for Nos. 141-148 a mean of 3,100 lbs. per square inch, and for Nos. 154-155 we get 2,550 lbs., or 82 per cent of the former. It will be observed that in the former about twice the volume of cement is used as in the latter.

In the case of the crushed rock screenings the mean tensile strength at 12 months is 650 lbs., where the volume of cement is about 54 per cent, the proportion being cement 1 to 1.8 screenings.

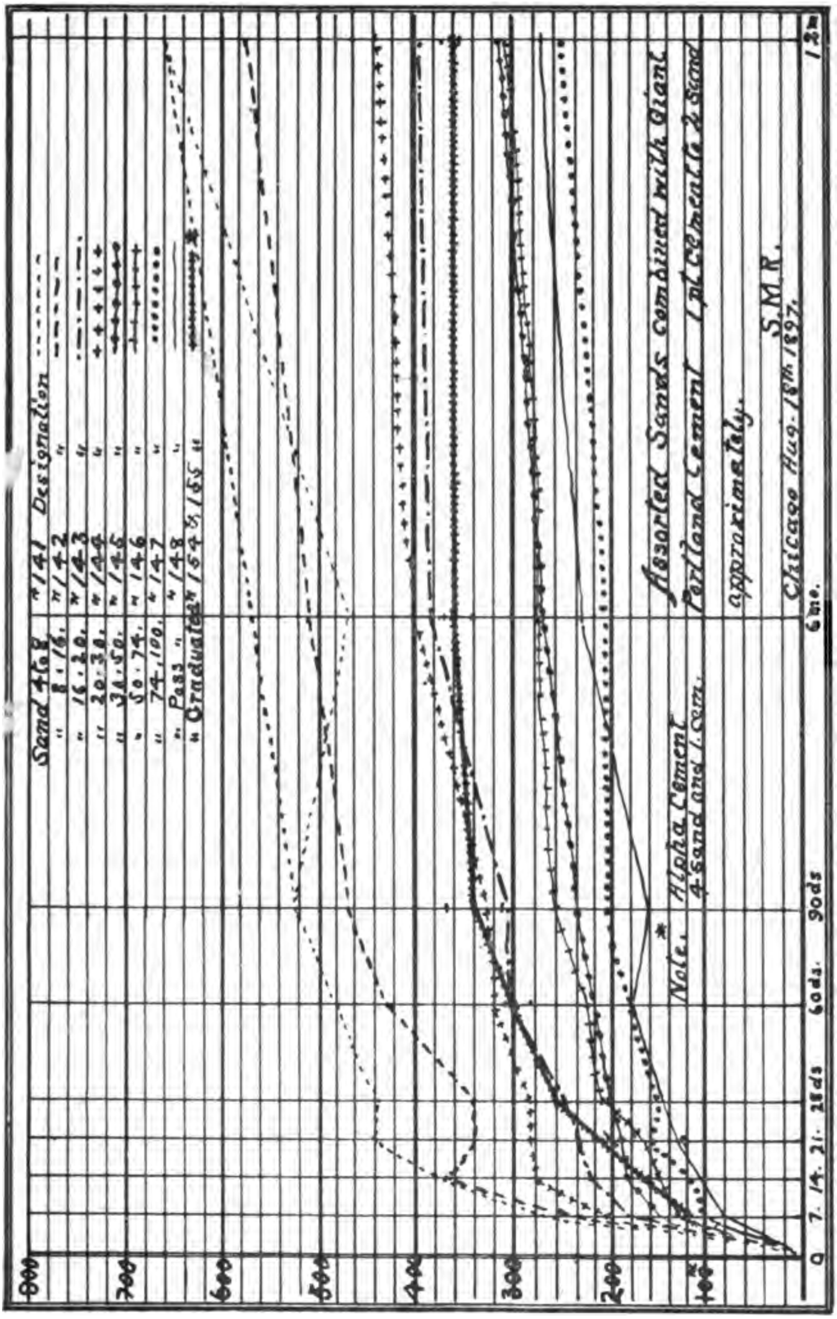
My No. 216, which consists of one part Empire cement to three parts screenings in the proportions that it comes from the crusher, has a tensile strength of 670 lbs., or more than the mean of the former.

For compressive strength, of the former at 12 months (at which leagth of time all these figures refer) is 4,150, while that of the latter is 4,000. Bedford stone tested at the same time gave for the blue 5,500 lbs. and for the buff 4,500 lbs.

That of the Bedford limestone was derived from 2-inch cubes, while that of the mortar was from broken briquettes from the tensile tests, one inch thick and four square inches area.

In tensile strength we find the screenings, with 20 per cent greater proportion of cement, is 40 per cent stronger than the assorted sands, while in compressive strength the screenings are only 25 per cent the stronger. We can well conceive that the rough and angular shapes offered by the crushed rock would afford a greater freedom in the chemical affiliation between the cement and stone than is offered by any sand, yet we doubt, when we consider the severe strain the stone has been subjected to in crushing, whether in long time it may be in any wise superior to the sand.

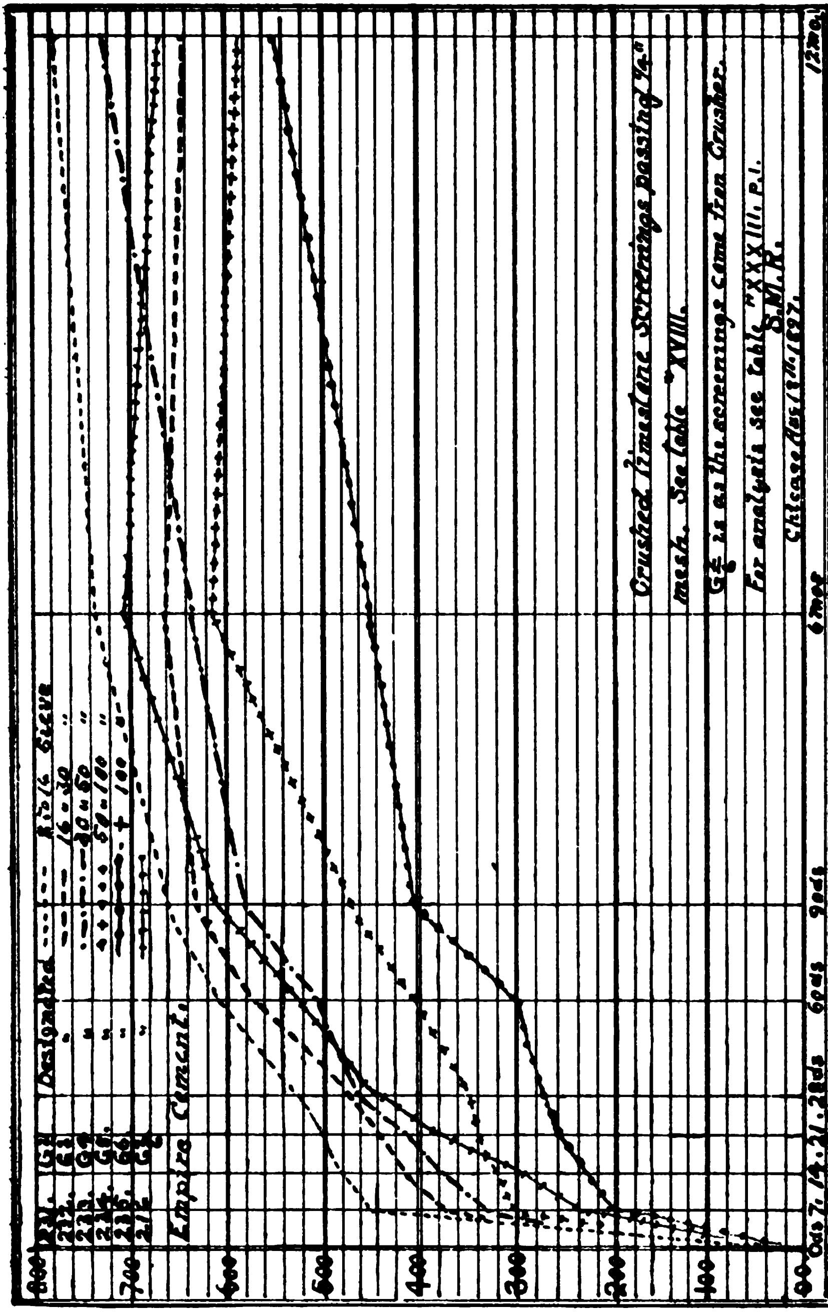
A comparison of the diagrams Figs. 159 and 160 will seem to show that the development of tensile strength after six months is greater and more uniform in the case of the sands, tending to confirm this.



Sand 4 to 8. #141 Designation
" 8-16. #142 "
" 16-20. #143 "
" 20-30. #144 "
" 30-50. #145 "
" 50-74. #146 "
" 74-100. #147 "
" Pass " #148 "
" Graduated* 154 & 155 "
Note. * Alpha Cement 4 sand and 1 Cem.
Assorted Sands combined with Giant Portland Cement 1 pt Cement to 2 Sand approximately.
S.M.R.
Chicago Aug. 18th 1897.
800
700
600
500
400
300
200
100
0
7.
14.
21.
28ds.
60ds.
90ds
6mo.
12m

"A"

FIG. 159.


Empire Cement.
Crushed Limestone Screenings passing ¼" mesh. See table "XVIII.
For analysis see table
S.M.R.
800
700
600
500
400
300
200
100
00
7 ds
9 ds
60 ds
6 mos
12 mos

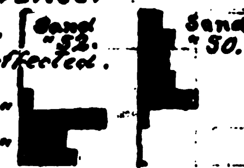
"B"

FIG. 160.

Effect of freezing on Concrete.

These blocks 12"×12"×5" were put up and exposed all winter

Lab No	Date	Name Cement	Sand	Proportion Cem.	Proportion Sand	Proportion Rock	% Water	% Dis-integra	Rating	Remark April 6th 1897.
290	1896 Dec 19th	Utica	#50	1.	1.	3.	18.4	.00%	1.	No 290. Strong and unaffected.
291	" 21st	Milwkee	#50	1.	1.	3.	18.4	" "	1.	No 291 " " "
292	" 22nd	Louvlle	#50	1.	1.	3.	18.4	" "	1.	No 292 " " "
293	" 23d	Rsndle	#50	1.	1.	3.	184	75."	3	No 293 Top and edges disintegrated Balance not strong. Can pick apart with fingers.
294	" 24th	Utica	#50	1.	2.	4.	12.6	01."	1.	No 294. Sound and strong.
295	" 24th	Mlwkee	#50	1.	2.	4.	126	00."	1.	No 295. Sound and Strong.
296	" 26th	Lvlle.	#50	1.	2.	4.	122	16 "	2.	No 296. Top and edges disintegrated Balance fairly firm. Cannot part with Fingers.
297	" 26th	Rsndle.	#50	1.	2.	4.	.22	75 "	3.	No 297. ¾ disintegrated Balance can be parted with Fingers.
300	1897 Jan. 6th	Utica.	#52	1.	2.	4.	18.2	20 "	2.	No 300. Top and corners disintegrated. Balance too firm to part with Fingers.
301	" 9th	Mlwkee	52	1.	2.	4.	18.3	40 "	3.	No 301. Top and sides disintegrated. Balance easily parted by Fingers.
302	" 9	Lvlle.	52	1	2	4.	17.6	25 "	2.	No 302 Top and sides disintegrated Balance difficult to part with Fingers.
a	b	c	d	e	f	g	h	i	k.	



Note.

The material was treated much as it would be on the street, the crushed rock being drenched before being added to the cement and sand. Nos 290 to 297 incl. were moulded in a wooden form while Nos 300 to 302 were made on three inches of dry sand.

It will be noted that the fineness of the No 52 sand which is much used in Chicago may have much to do with the failure of the three latter cases, aided perhaps by the rapid absorption of the water from the concrete by the sand substratum.

TABLE XXIV.

Characteristics of "assorted Sands.												Laboratory Journal No VIII. (28) "G"			
Lab. No. Brq No	Sand Between sieves.	Sand Cu. ins	Cement Cu. ins	Total" Sand & Cement	Total " Mixed Dry ins	Per cent Cement absorbed	Vol mort Finished Brq	Shrinkage Percent of orig'l	Weight of Cemt. pr cu"	Weight Sand pr cu"	Voids of Sands per cent	Shrinkage	Incr on adding water	
								%		ozs.		%	cu. ins	
141	4 & 8	80"	38.62	118.62	94.6	60%	94.7"	80.5	.9770	.9738	38.62	20.16	0.10"	00.01
142	8 & 16	80"	34.37	114.37	95.3	55 "	94.6	82.7	"	.9734	37.34	17.28	- - -	- - -
143	16 & 20	80"	37.76	117.76	93.5	64 "	94.6	80.3	"	.9584	37.76	19.68	1.10"	01.16
144	20 & 30	80"	36.31	116.31	97.3	52 "	103.2	87.9	"	.9328	36.31	11.27	5.9"	05.72
145	30 & 50	80"	36.03	116.03	100.1	44 "	107.5	92.8	"	.9430	36.03	7.35	7.4"	06.90
146	50 & 74	80"	35.69	115.69	103.4	34 "	111.8	96.6	"	.9053	35.69	3.36	8.4"	07.51
147	74 & 100	80"	36.80	116.80	104.3	34 "	112.8	96.8	"	.9000	36.80	3.42	8.5"	07.55
148	Pas. 100	80"	33.26	113.26	101.8	34 "	106.7	94.2	"	.9578	33.26	5.79	4.9"	04.58
154	Equal	92.32"	20.36	112.68	102.6	50 "	106.7	94.7	"	1.1359	22.05	5.30	4.10"	03.83
155	Grade.	103.20"	24.98	128.18	114.6	54 "	120.1	93.7	"	1.0909	24.21	6.30	5.5"	04.58
		m	n	o	p	q	r	s	t	u		v	w	x
				2m+n		$\frac{n-(o-p)}{n}$		$\frac{r}{o}$				$\frac{o-r}{o}$	r−p	$\frac{r-p}{r}$

TABLE XXV.

(Note to Table XXV.)

Column "m" gives the cubic inches of sand used in the test.
" "n" " " " " " Cement " " "
" "o" gives the sum of these
" "p" gives the cubic inches of both when thouroughly mixed.
" "q" gives the proportion of the cement entering the voids of the sand when mixed dry.
" "r" is the cubic inches of the finished mortar.
" "s" is the proportion that the finished mortar bears to the original quantities. $\frac{r}{m+n}$,
" "t" Weight per cubic inch in ozs Av. Cement. (Giant.)
" "u" " " " " " " " Sands.
" "v" Per cent excess of material measured dry that would be required for any given vol,
" "w" is the cubic inches increase in volume due to adding the water.
" x is the proportion of the same.

Note. The unit of weight is Ozs Avoirdupois with decimals to 4 places, the scales weighing to grains. (7000 to 1 lb Av)

Sands are thoroughly dried before sifting, and well shaken down and struck for measure. All measures are verified by water at 60° F.

Cements are thouroughly shaken, expelling all air hence show heavier than the understood commercial weight.

XII.

REPORT UPON THE CONDITION OF THE IRON WORK IN THE OLD UNITED STATES POSTOFFICE AND CUSTOM HOUSE BUILDING IN THE CITY OF CHICAGO.

Read July 7, 1897.

CHICAGO, Dec. 15, 1896.

MR. JOHN F. WALLACE, *President Western Society of Engineers.*

DEAR SIR—Your Committee appointed to examine and report upon the condition of the iron work in the old United States Postoffice and Custom House Building in the City of Chicago during the wrecking of the same submit the following report:

This building was built during the years 1871 to 1875 inclusive, and the metal work used was of iron. The floor was supported on concrete arches with number 14 corrugated iron centers, and carried on iron beams. This corrugated iron in most instances shows the original gloss received in the process of rolling, and exhibits no signs of deterioration, except where it has been directly exposed to the weather. The corrugated iron and beams appear to have been well painted with red lead paint, and most of this paint remains in an excellent state of preservation.

The only metal work in the building that is found to have suffered from corrosion is the corrugated metal lathing, which was of number 18 gauge iron. This is found to be very generally covered with a coating of rust which, when cleaned off, is found to be so thin as not to appreciably reduce the original thickness of the plate. Where the lime plaster adhered to the lathing, the rust is not so noticeable as it is in the spaces on which no plaster is attached. It is the opinion of your Committee that this rusting resulted from the original moisture in the plaster.

While some of the iron work in the roof is found to be considerably rusted, it is due to local conditions, such as leaks in the roof or to the iron being near to openings.

After the wrecking of the building had progressed so far as to leave the iron exposed to the weather, it was not possible to determine what the condition of the iron was before being uncovered. Therefore most of the Committee's investigation was confined to the two upper floors of the building.

In a few instances evidence was found which indicated that the first coat of paint applied in the shop was probably iron oxide paint instead of red lead. The evidence, however, was too slight to be conclusive.

he conclusion of your Committee derived from the examina- of this building is that iron properly painted before being ced in a building, and reasonably protected from air and moist- does not deteriorate to any serious extent. The iron in this ding is apparently in as good condition when uncovered after nty odd years as it was when first put in place; but the paint ering the same is found to be dry and brittle, having partly its life. Yours respectfully,

W. L. Stebbings,
T. L. Condron.

DISCUSSION.

r. Gerber: A few things appeared in the paper on the old office which are of interest, considered with other discussions ch have been current in periodicals, and also in the reports re other societies. The committee state that they examined e particularly the upper floors. During the winter I had a e leisure and I examined quite a number of pieces which e from the lower floors. In scraping the paint from these es it was found without exception that under the red lead e was a paint of the ordinary mineral color which was pre- ably iron oxide. No analysis has been made of it, therefore ing definite can be said. A great many of the connections been cut apart, and these indicated that the metal was origin- painted in the shop with some ordinary paint, such as is monly used in shops, and that the red lead had not been ap- d till after erection, because in these connections, where the rent pieces of metal had been in contact, a brownish paint very plainly to be seen appearing almost fresh, and there an entire absence of red lead.

he condition of the metal as described by the committee is tically the same as it seemed to me, namely, quite good; and this connection it is rather interesting to note a report de in December, 1896, before the American Society of Me- nical Engineers, by Mr. M. P. Wood, who has written very usely on the subject of paint. He is apparently very much osed to iron oxides, but is decidedly in favor of red lead. In paper he says it is a crime to put iron oxide on any struc- , that probably every structure which has been painted with oxide for the first coat will go to pieces in a comparatively t time, and mentions a case in New York. The postoffice ding doesn't seem to bear out any such statement.

the same paper another statement is made relative to the ing of a vessel on the coast of Great Britain. The vessel a cargo of "burnt" ore. It sank, and after being in the sea ut a week was raised, and the machinery which had not been ted was corroded to the depth of an eighth of an inch or e. The author of the paper concludes that, notwithstanding

there was four or five per cent of free sulphate of copper pre in this ore, which was sufficient to eat up 3,200 pounds of i the whole destruction was due to the iron oxide in the ore was a little interested in the matter and took pains to write to owners of the vessel, and received the statement from them tha cargo consisted of burnt ore, the residue after extracting sulp from cupreous pyrites, which was being transported from place to another to extract the copper it contained. About per cent of that ore was iron oxide, but the rest was a cop compound. In some of the other papers which Mr. Wood written there are ten or a dozen instances cited showing v conclusively that the combination of sulphate of copper with water is about the worst thing iron can be exposed to, the c bination corroding iron very rapidly. His conclusion, theref that iron oxide was the cause of the destruction of the m work in the vessel seems to be entirely erroneous. The ot statement, therefore, that a building in New York had been tirely corroded because it had been painted with iron ox would carry very little weight; that the paint was not the ca is further corroborated in this case of the postoffice.

The committee state that the red lead paint was very br and had lost part of its life. The trouble with red lead is, un it is properly mixed and applied, it never has very much Red lead, when mixed and applied properly, is a good paint, until recently very few jobs of red lead painting were prop done, the trouble being that the red lead was allowed to set fore being applied, and then it always became brittle in the that the red lead paint on the postoffice iron is brittle.

From the report of the committee it is pretty evident that need not fear that our buildings, if properly painted with good paint, are going to come down because of rust.

The Chairman: Mr. Gerber, if I might ask, did you look i the building closely to see if the iron work was all closed tightly?

Mr. Gerber: Most of it was closed in tightly.

XIII.

CAUSES OF THE VARIABLE EFFICIENCY OF STEAM BOILERS AND THEIR INFLUENCE ON TESTS.

By F. G. Gasche, Mem. W. S. E.

Read July 21, 1897.

The efficiency of a boiler is a quantity subject to many definitions. It is usually considered sufficient to state as the efficiency the ratio of the actual evaporation per pound of fuel to the "theoretical" evaporation; assuming in the latter case that all the heat generated by the complete combustion of the fuel had been transferred to the water and steam. Recently, it has been proposed to give the efficiency of a steam boiler in terms the ratio of the heat units absorbed, to the total heat equivalent of the fuel, expressed in British Thermal units. This proposition will be found unsatisfactory in time, when the principle is observed that "heat cannot by itself pass from a colder to a hotter body." Temperature measurements will necessarily form the basis of the experimental determination of efficiency, so that it is important to observe what temperatures enter the computations. When the temperature of the products of combustion has been lowered to that of the steam, it is evident that all of the available heat has been utilized. It is therefore the minimum temperature which should enter the expressions for efficiency, as distinguished from the initial temperature of the feed-water, the use of which the above method of computing efficiency proposes. Granting that the reference to "heat units absorbed" is a step in advance in the expression of the efficiency, it is no means of evading the chaotic condition of many existing records of boiler performance, or of records of this nature made in the future, should the prevalent method of making trials continue. These records do not appear to be incomplete when they are consulted. Is it not a fact that we see the composition of the flue gases, the temperatures of the boiler room, and the air, the analysis, and pyrometric measurement of the heat equivalent of the fuel, and the height of the barometer, even the "state of the weather," to say nothing of various essential weights and measures? All of this information ought to make the data complete; but why the remarkable variation of efficiency on the occasion of successive trials, with the same boiler and fuel, and with surrounding conditions the same? It is because the prevalent methods of making boiler trials, by which this efficiency is measured, *do not recognize the important influence of the rate of combustion of the fuel.*

We may know that a British Thermal unit, whether delivered in a second or in an hour, is the same quantity of heat, yet we cannot ignore the fact that the variable resistance of materials to the transfer of heat introduces the element of time. This effect is prominent in the materials involved in generation of steam in large quantities.

To the great uncertainty of the results of many boiler trials may be attributed the indifference to the possibility of improvement in operation of existing boilers, or of their design. Unskillful experimenters are partially to blame for this, while the religious observance of "rules for conducting boiler trials" has contributed its share to the wide variations of boiler service, where consistent results might be expected. It is important to observe in this line of experimental work that a boiler trial is *essentially* a measure of *rates*. The ultimate result depends on rate of delivery of the feed water, rate of coal consumption, and rate of ejection of moisture with the steam. The first requisite for the measurement of these rates is to maintain constant the conditions upon which the operation of the boiler depends; meaning, among other things, that the demands for steam from a boiler under test must be maintained as nearly uniform as it is possible to make them. In the absence of connection to other boilers by distributing mains, or with an engine under constant load, it is advisable to send the steam to a condenser of appropriate size. When the condenser is available and the issue of the experiments is of sufficient importance to warrant the expenditure of steam in this way, it effectually disposes of the vexatious question of moisture in the steam. The condenser, combined with a suitably arranged measuring tank, is in effect a Barrel Calorimeter on a large scale, from which the portion of heat lost by radiation is so small that it may be neglected, in view of the fact that all of the heat delivered from the boiler is measured.

Notwithstanding the eminent authority for the suggestion of the method trials should not be started by withdrawing the fuel on the grates, and rekindling with wood and fresh coal. Nor should the fires be allowed to burn out at the close of the trial. Had the effects of this method been studied from graphical representations in the manner illustrated in Fig. 163, it is probable that qualifications would have accompanied the suggestion such as to prevent the general use of a method open to serious objections. The fact of the matter is that the furnace loses more heat in the process of rekindling the fires than the heat equivalent of an amount of coal which would far exceed the estimate of coal on the grates due to a "flying start." Only the difference of the estimates of coal on the grates at start and finish will enter the item of total coal used. Samples of the fuel should be dried to determine the moisture in the coal immediately after the test. Evaporation should be referred to the pound of dry coal with as much reason as the use of the unit "from and at 212° F."

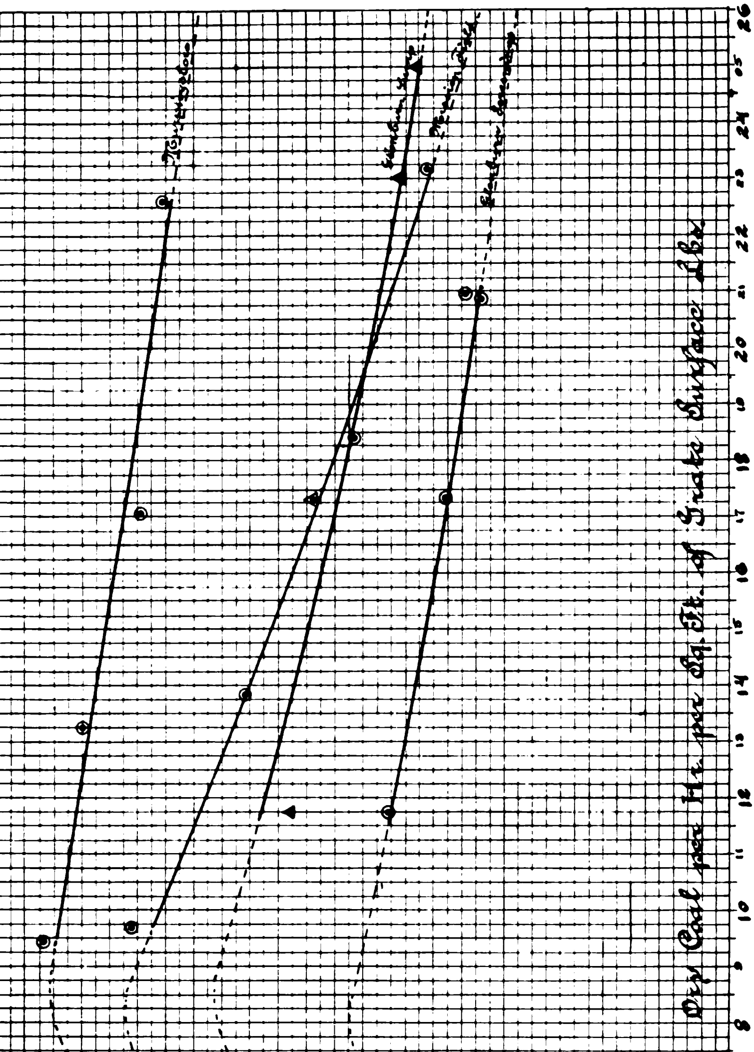


FIG. 162. Graphical representation of $E' = \frac{C}{1 + A K'}$

In Fig. 163, the curve of feed water weights O D C B E shows a total feed water of 68,500 lbs., or a rate of 6,850 lbs. per hour, assuming that the fire had been permitted to die out, so as to give the drop in curve shown by B E. The distortion O D C is an error of rates introduced by withdrawing all of the fire at the start of the test, and rekindling with wood and fresh coal. The approximate "rate" of delivery of feed water is shown by an average line O E to be 7,540 lbs. per hour. More accurately, by taking the portion of the feed water curve between 9:30 A. M. and 4:15 P. M., during which time the conditions were reasonably constant, the "rate" of feed water delivery is found to be 8,650 lbs. per hour. Again, by the curve of coal weights O C H G, the "rate" of delivery of coal, due to allowing the fires to die out at the end of the trial, represented by the line O G, is 1,200 lbs. per hour, while the actual rate is 1,250 lbs. per hour. Finally, we determine the observed evaporative value $= \frac{8650}{1250} = 6.93$ lbs. of water per pound of coal, instead of $\frac{6850}{1200} = 5.72$ lbs., in consequence of the more accurate measurement of "rates" of delivery of water and fuel. In order to avoid the dangers incident to prevalent methods of conducting trials, it is advisable to deliver the coal to the fire at regular intervals, in predetermined quantities. Commence this work at least an hour before the beginning of the trial, adjusting the draft and steam demands so that all conditions attending the operation of the boilers will be reasonably constant. Above all, prevent a flow of air into the fires to such an extent that there is a marked tendency to burning holes. Under such circumstances only can consistent results be expected.

Rankine found it necessary in his study of the performances of steam boilers and attemps to rationalize the results to which he had access, to evolve the analytical expressions for two ratios, viz.: efficiency of heating surface, and efficiency of furnace. The efficiency of furnace is represented by—

$$\frac{E'}{E} = \frac{BS}{S+AF} \qquad (1)$$

where,

B. is a fractional multiplier to allow for miscellaneous losses of heat, to be found by experiment.

A. is a constant.

S. is the whole heating surface of the boiler.

E. is the theoretical evaporative value (from and at 212° F. per pound of fuel.)

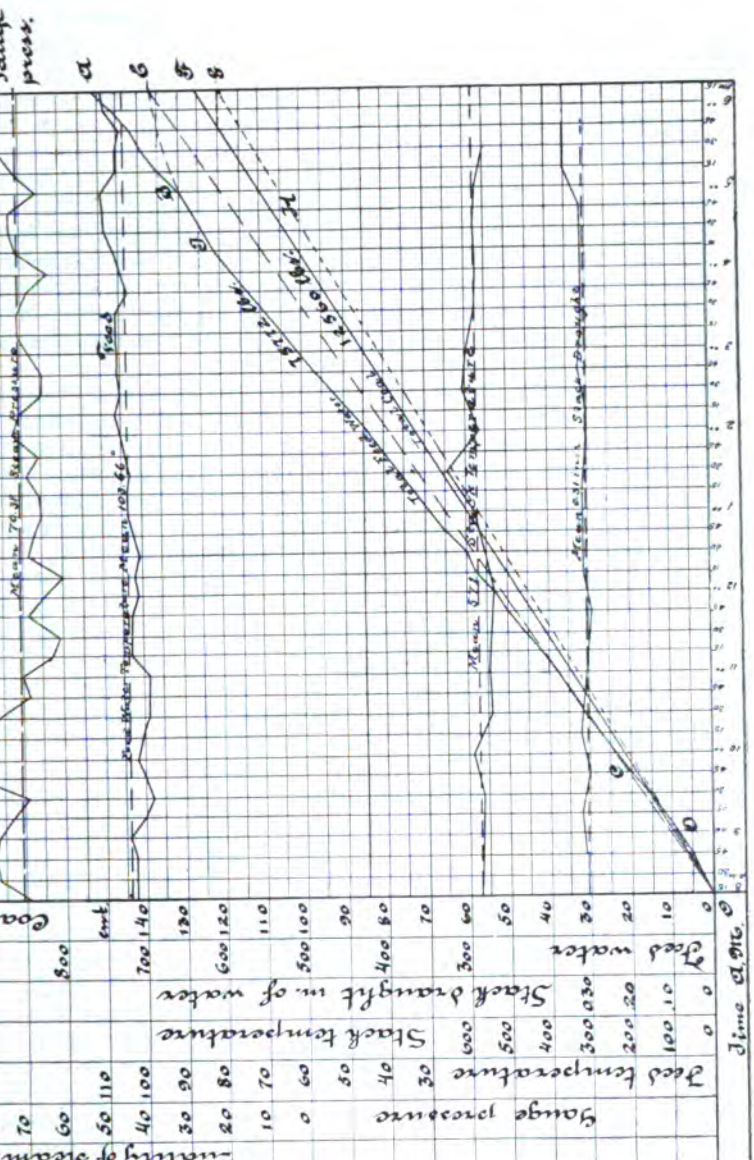


FIG. 163. Graphical Log of a Boiler Trial. Illustrating errors in rates due to errors in start and finish.

E' is the available evaporative power (from and at 212° F. per pound of fuel).

$$R = \frac{F}{S} \text{ ratio of coal burned to heating surface,}$$

and

$$\frac{E'}{E} = \frac{B}{1 + A\frac{F}{S}} = \frac{B}{1 + AR} \qquad (2)$$

Concerning this expression Rankine says: "The formula is framed on the supposition that the admission of air and the management of the fires are such that no appreciable loss occurs, either from imperfect combustion or excess of air, the construction of the furnace and the mode of using it being the best possible for each kind of boiler."

In this expression (2) E is a constant for an average lot of a given kind of fuel. E' is variable, as a later investigation will show. When a number of experimental results, such as those collected in Table XXVI, have been obtained from boilers similar in size, type, and form of furnace, they may be studied with reference to the varying rates of combustion of fuel per square foot of grate surface. Equation (2) then becomes

$$\frac{E'}{E} = \frac{B}{1 + AR'} \qquad (3)$$

where,

$$R' = \frac{F}{G} = \text{fuel per square foot of grate surface.}$$

The product E B is a constant, and we may say

$$E' = \frac{C}{1 + AR'} \qquad (4)$$

The experimental evidence given in Table XXVI is indicative of what the record of a great many boiler trials tend to show, viz.:—within the restrictions which Rankine placed on the application of the formula, it expresses the law of variation of boiler efficiency. The curve is a portion of the right hyperbola, and may be designated as the "curve of evaporation;" limited, at one extremity, by the condition that "the admission of air and the management of fires are such that no appreciable loss occurs from excess of air," and at the other extremity by the condition that such losses are not introduced by "imperfect combustion." These limits are further influenced by the kind of fuel, kind and size of boiler, size of grate, and amount of draft.

It must be understood that the use of the same coal under boilers widely different in type or size will generally produce a

fferent "curve of evaporation," because such a change will in-
lve important alterations in both the amount and the distribu-
n of the heating surfaces.

The boilers upon which the trials summarized on Table XXVI
re made are shown in detail on Plate II, together with the
re important dimensions. The several trials were executed on
e lines suggested in the preceding pages. Table XXVI con-
ns items sufficiently complete for the purpose in hand, though
does not contain all of the derived results pertaining to the
veral fuels. From this table another, Table XXVII, has been
nstructed, involving, among other things, the equation of the dif-
ent curves of evaporation. These results have been shown
aphically on the diagram, Fig. 161, wherein the departures of the
veral observation points are visibly apparent. The addition or
btraction of another observation point to the group pertaining
any one curve, which was derived from a boiler trial made with
ual care and within the rates of combustion there shown, would
t materially affect the form or position of that curve. We may
, therefore, that the departure of the observation points from
e curve indicate probable errors of the trials to which they
ply. Naturally, an increase in the number of trials made with
ual precision will more accurately locate the curve. Many engi-
ers who have occasion to study this class of problems can
call instances where certain evaporative values of a coal were
ported in such a manner that the evaporation per pound of dry
al at an ordinary rate of firing was much lower than the evap-
ation when heavy rates prevailed. In view of the foregoing we
e forced to one of two conclusions—either abnormal conditions
isted at the boiler when one or both of the trials were made,
one of the trials was widely in error.

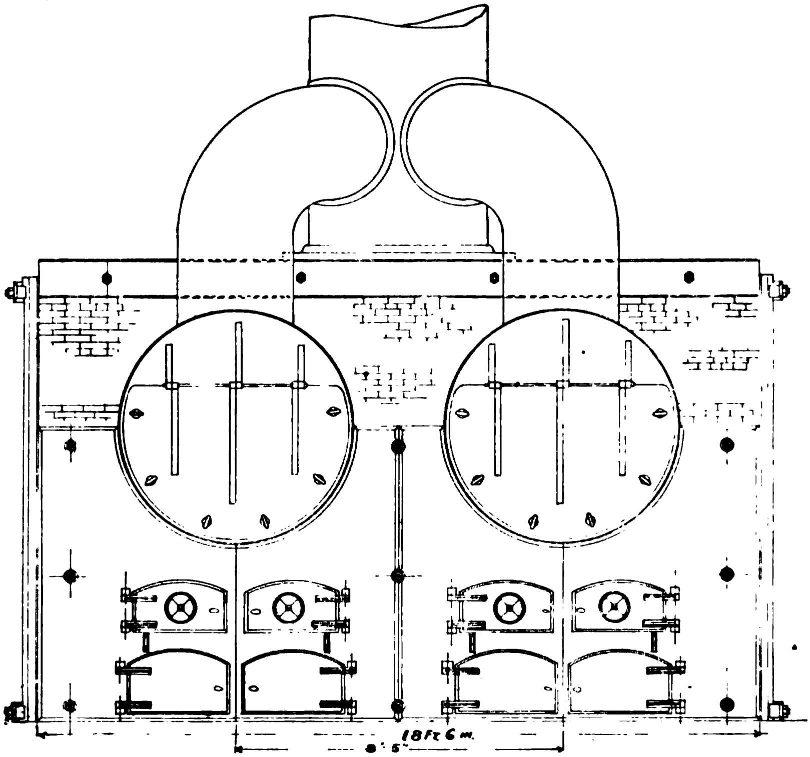
The use of sixteen boiler trials as a basis of the derivation of

---

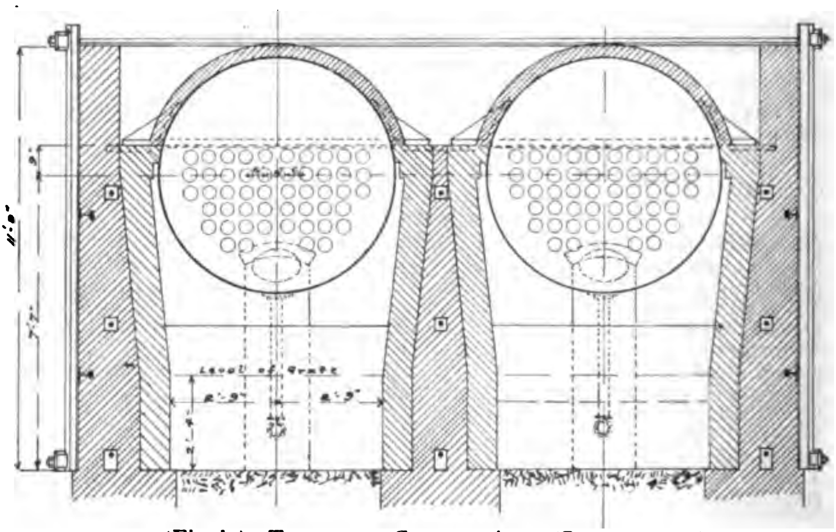
PLATE II.—BOILERS AND SETTINGS (see Figs. a, b, c, and d) used in
ls

of { Murphrysboro coal
Mission Fields coal
Glenburn lump coal
Glenburn screenings.

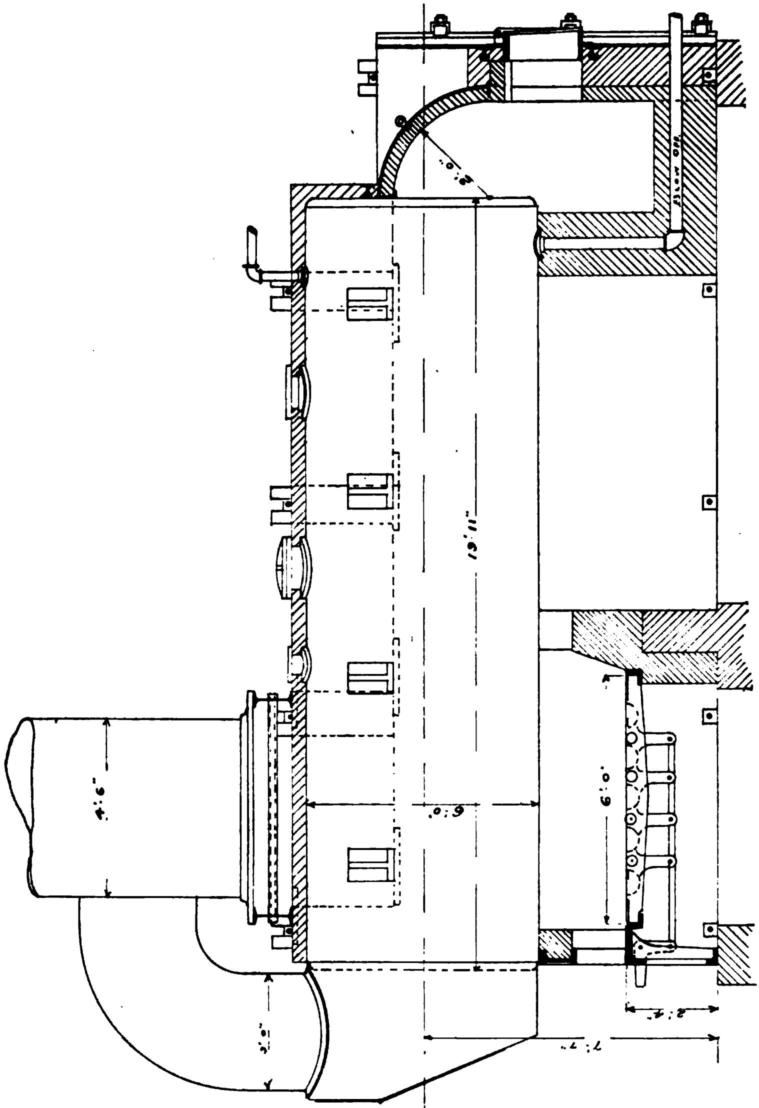
ameter of shell outside	6 ft. ¾ in.
ngth of shell outside	19 ft. 11 in.
mber of flues	50
ameter of flues	4½ in.
ngth of flues	19 ft.
ameter of stack	54 in.
ight of stack	60 ft. above grade
ameter of steam pipe	8 in.
tal heating surface	1352 sq. ft. each
ngth of grate	6 ft.
dth of grate	5 ft. 6 in.
tal grate surface	33 sq. ft. each
tio of heating and grate surface	41 to 1



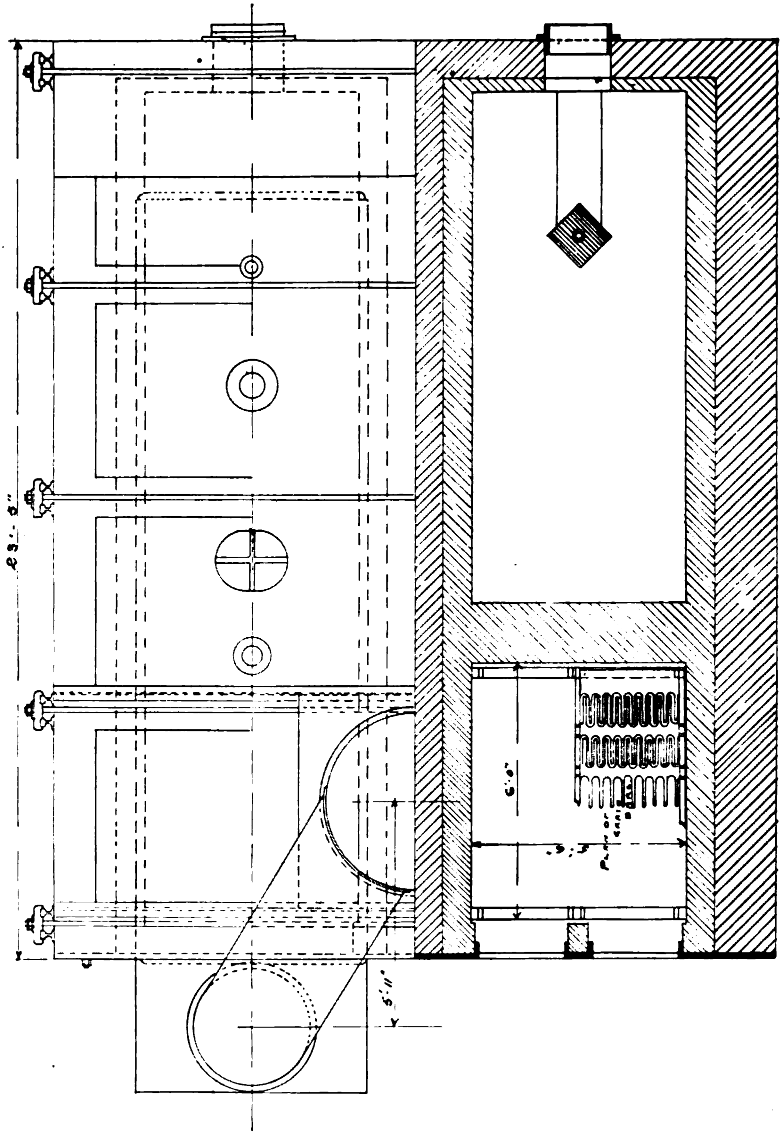
(Fig. a.) End Elevation. (See page 429.)



(Fig. b.) Transverse Cross-section. (See page 429.)



(Fig. c.) Longitudinal Vertical Cross-section. (See page 429.)



(Fig. d.) Horizontal Plan and Section. (See page 429.)

what may be termed the law of variation of boiler efficiency seems warranted, in view of the fact that they were taken at random from a group of about 160 trials made upon the same boilers, from which, among other purposes, the relative commercial value of over twenty different kinds of coal were determined. All of these trials gave consistent results.

Kind of Boilers		72 in. x 20 ft. Horizontal Tubular Boilers. Heating Surface 1352 sq. ft. Grate Surface, 33 sq. ft.															
Kind of Coal		Murphysboro.				Mission Field.				Glenburn Lump.				Glenburn Screenings.			
Number of Trial		16	18	19	20	36	37	38	39	59	60	61	62	63	64	65	66
Date of Trial		5-11 '93	5-16 '93	5-17 '93	5-18 '93	6-19 '93	6-20 '93	6-21 '93	6-22 '93	5-14 '95	5-15 '95	5-16 '95	5-17 '95	5-18 '95	5-20 '95	5-21 '95	5-22 '95
Duration of Trial	Hrs.	10	10	10	10	10	10	10	10	6	12	12	12	12	8	12	9
Averages.																	
Aver. S. Gauge Pressure	Lbs.	75.06	73.20	73.02	69.34	72.91	75.53	74.67	73.98	79.24	80.96	76.74	81.29	81.24	78.01	78.54	77.98
" F. Water Temperature, Fahr.	Deg	96.77	87.88	78.59	88.65	108.6	104.8	106.2	102.8	75.70	83.60	89.40	89.2	90.0	80.9	82.1	82.8
" Flue Gas " "	"	532.	576.	607.	447.	450.	437.	578.	678.	461.	647.	574.	644.	465.	532.	519.	554.
" External Air " "	"	65.	48.	58.	61.	85.	83.	89.	82.	44.	45.2	52.3	62.0	60.0	44.5	54.6	69.6
" Boiler House " "	"	79.	67.	76.	75.	96.	93.	89.	82.	57.	58.5	65.0	74.0	70.8	62.2	66.8	79.4
" Stack Draft (water column)	In.	0.292	0.305	0.288	0.287	0.264	0.280	0.265	0.346	0.333	0.415	0.358	0.577	0.389	0.345	0.316	0.363
" Quality of Steam	%	99.05	98.78	98.87	99.12	99.01	98.82	98.82	98.72	99.59	98.96	98.92	.9846	98.97	98.70	98.86	98.97
" Factor of Evaporation		1.154	1.161	1.163	1.161	1.142	1.146	1.144	1.148	1.177	1.169	1.163	1.163	1.163	1.172	1.170	1.169
" Horse-Power of Two Boilers	H P.	233.	286.	373.	172.	162.	207.	256.	300.	174.	306.	250.	323.	156.	250.	215.	243.
Totals.																	
Total Feed Water delivered	Lbs.	70315.	86030.	111800.	51438.	49310.	64347.	77864.	91158.	30390.	109291.	90001.	117783.	56095.	59867.	76938.	69792.
" " " actually evaporated	"	69648.	84980.	110530.	50985.	48818.	63580.	76941.	89990.	30264.	108180.	89028.	115960.	55460.	59142.	76060.	69072.
" Equivalent Evap. f and at 212° F.	"	80382.	98660.	128554.	59210.	55742.	72870.	88042.	103270.	35613.	126400.	103500.	134900.	64476.	69298.	89002.	80762.
" Coal Fired	"	9245.	11910.	15785.	6600.	6530.	9410.	12600.	15840.	4832.	18978.	14261.	20627.	9514.	11351.	14251.	12928.
" Combustible Fired	"	8238	10612.	14066.	5882.	5600.	8070.	10806.	13592.	4134.	16235.	12200	7645.	7824.	9335.	11720.	10631.
" Dry Coal Fired	"	8739.	11250.	14920.	6237.	6296.	9088.	12152.	15272.	4638.	18218.	13690.	19800.	9133	10897	13680.	12410.
Hourly Quantities.																	
Actual Evaporation per hr.	Lbs.	6965.	8498.	11053.	5099.	4882.	6358.	7694.	9000.	5044.	9014.	74192.	9664.	4622.	7393.	6338.	7675.
Equivalent Evap., f and at 212° F. "	"	8038.	9866.	12855.	5921.	5574.	7287.	8804.	10327.	5936.	10534.	8624.	11241.	5373.	8662.	7416.	8074.
Coal Fired "	"	924.5	1191.	1578.	660.	653.	941.	1260.	1584.	805.4	1581.	1188.	1719.	792.8	1419.	1188.	1437.
Combustible Fired "	"	823.8	1061.	1407.	588.	560.	807.	1080.	1359	688.9	1353.	1017.	1470.	652.	1167.	976.7	1181.
Dry Coal Fired "	"	873.9	1125.	1492.	623.7	629.6.	908.8.	1215.	1527.2	773.0	1518.	1141.	1650.	761.	1373.	1140.	1380.
Evaporation.																	
Actual Evaporation per lb. of coal	Lbs.	7.53	7.14	7.00	7.72	7.48	6.76	6.11	5.68	6.26	5.70	6.24	5.62	5.82	5.21	5.34	5.34
Equiv. Evap. f & at 212° F. per lb. of coal	"	8.70	8.30	8.14	8.97	8.54	7.75	6.99	6.52	7.42	6.60	7.26	6.54	6.78	5.89	6.25	6.25
" " f & at 212°F. pr lb. of dry coal	"	9.20	8.78	8.62	9.49	8.85	8.04	7.25	6.76	7.68	6.94	7.56	6.81	7.06	6.36	6.51	6.49
Actual " per lb. combustible	"	8.45	8.01	7.86	8.67	8.72	7.89	7.12	6.62	7.32	6.67	7.30	6.57	7.09	6.34	6.49	6.51
Equiv. " f & at 212°F. pr lb. comb'tble	"	9.76	9.31	9.14	10.07	9.45	9.04	8.15	7.60	8.62	7.79	8.48	7.65	8.24	7.42	7.59	7.60
Hourly Ratios to Heating and Grate Sur.																	
Actual Evap. per Sq. ft. of H't'g Sur.	Lbs.	2.57	3.14	4.09	1.88	1.81	2.35	2.85	3.33	3.73	6.67	5.49	7.15	3.42	5.46	4.69	5.68
Equiv. " f & at 212 " " " " " "	"	2.97	3.65	4.75	2.19	2.06	2.70	3.26	3.82	4.39	7.79	6.38	8.31	3.97	6.41	5.48	6.64
Coal Fired " " " " " "	"	0.342	0.441	0.583	0.244	0.242	0.348	0.466	0.586	0.595	1.169	0.879	1.271	0.586	1.05	0.878	1.063
Combustible Fired " " " " " "	"	0.304	0.392	0.520	0.217	0.207	0.299	0.400	0.514	0.510	1.001	0.752	1.088	0.482	0.863	0.722	0.874
Coal Fired " " " " Grate "	"	14.01	18.04	23.92	10.00	9.89	14.26	19.09	24.00	12.20	23.96	18.03	26.04	12.01	21.50	18.00	21.76
Dry Coal Fired " " " " " "	"	13.21	17.05	22.61	9.45	9.54	13.77	18.41	23.14	11.71	23.00	17.28	25.03	11.53	20.81	17.27	20.89
Combustible Fired " " " " " "	"	12.45	16.08	21.30	8.91	8.41	12.20	16.36	20.59	10.41	20.50	15.41	22.27	9.88	17.68	14.80	17.90

TABLE XXVII. EXPERIMENTAL PROOF OF $E' = \dfrac{C}{1+AR'}$

Name of Coal.	Equation.	Dry Coal per hr., per sq. ft. of Grate.	Evaporation from and at 212° F. By Equation.	Evaporation from and at 212° F. By Observation.	Differen
Murphrysboro	$E' = \dfrac{10.205}{1+0.00856\ R'}$	9.45	9.44	9.49	−0.05
		13.25	9.16	9.20	+0.0
		17.05	8.90	8.77	−0.04
		22.61	8.55	8.62	+0.07
Mission Field	$E' = \dfrac{11.29}{1+0.0294\ R'}$	9.54	8.69	8.85	+0.16
		13.77	8.04	8.04	0.00
		18.41	7.33	7.25	−0.0
		23.14	6.72	6.76	+0.04
Glenburn Lump	$E' = \dfrac{9.155}{1+0.0139\ R'}$	11.71	7.87	7.68	−0.19
		17.28	7.38	7.56	+0.1
		23.00	6.94	6.94	0.00
		25.00	6.80	6.81	+0.01
Glenburn Screenings	$E' = \dfrac{8.00}{1+0.01226\ R'}$	11.53	7.01	7.06	+0.04
		17.27	6.60	6.51	−0.09
		20.81	6.37	6.36	−0.01
		20.89	6.365	6.49	+0.12

We have the assurance of an authority no less eminent tha Charles E. Emery that such a law is unquestionably true f anthracite coal under a given boiler, either horizontal tubular vertical tubular. Experiments are not sufficiently complete this time to warrant the unqualified statement of the law for fu oil and fuel gas, but the evidence in hand seems to indicate th there is no inherent property of those fuels to cause them to d viate from the tendencies noted for the solid fuels.

From what has been said, it is evident that the peformance a boiler should be derived from a series of trials, in whch t distinguishing feature is the deliberate variation of the i rate combustion for the successive tests. A few isolated trials wi give no conclusive evidence of the evaporative value of a give fuel under a given boiler, or of the value of other quantities f which trials are made. The method here proposed will permit exact duplication of results within small limits of error, even wit independent observers, pre-supposing equal care.

Intimately associated with the efficiency of boilers will b found the reciprocal effect of the various regenerative device particularly feed heaters. Their application to a power plant wi result in a compound fuel saving, which may be divided into tw parts:

1st. The saving due to the heat actually recovered, having fuel equivalent.

$$\text{Saving in per cent} = \frac{100\,(Q-q)}{H-q} \qquad (5)$$

here,
H = Total heat in one pound of steam at the boiler pressure reckoned from the freezing point.
Q = "Heat of the Liquid" corresponding to the final temperature of the feed water.
q = "Heat of the Liquid" for the initial feed temperature.
2nd. The saving due to the increased evaporation per pound of fuel, the quantity of steam generated before and after the attachment of the feed heater being the same, because the first mentioned saving permits a lower rate of combustion.
Let W = pounds of dry coal burned per hour.
G = grate surface.
The steam evaporated per hour is,

$$WE' = \frac{WC}{1+AR'} \qquad (6)$$

The fuel equivalent per hour, due to the heat returned by the feed heater is,

$$W \left\{ \frac{Q-q}{H-q} \right\} \qquad (7)$$

The reduction in the rate of firing the coal is,

$$\frac{W}{G} \left\{ \frac{Q-q}{H-q} \right\} = R' \left\{ \frac{Q-q}{H-q} \right\} \qquad (8)$$

Under these conditions the evaporation per pound of dry coal will be

$$E'' = \frac{C}{1+AR' \left\{ 1 - \frac{Q-q}{H-q} \right\}} \qquad (9)$$

The increased steam delivery per hour which would occur *simultaneously* with the saving due to (7) will be

$$W(E''-E') \qquad (10)$$

Assuming that the quantity of steam generated is the same before and after the use of the feed heater, the potential increase will have a fuel equivalent,

$$\frac{W}{E'}(E''-E') \qquad (11)$$

The total fuel saving per hour in pounds of dry coal is,

$$\left\{ \frac{Q-q}{H-q} + \frac{AR' \quad (Q-q)}{(H-q)\ (1\ AR')} \right\} = W \left\{ \frac{Q-q}{H-q} \right\} \cdot \left\{ \frac{1+2\ AR'}{1+AR'} \right\} \qquad (12)$$

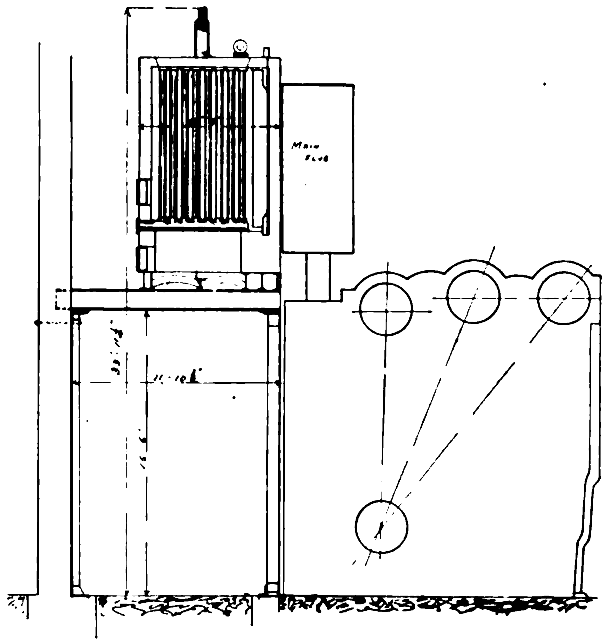
The saving in per cent is therefore,

$$100 \left\{ \frac{Q-q}{H-q} \right\} \cdot \left\{ \frac{1+2\ AR'}{1+AR'} \right\} \qquad (13)$$

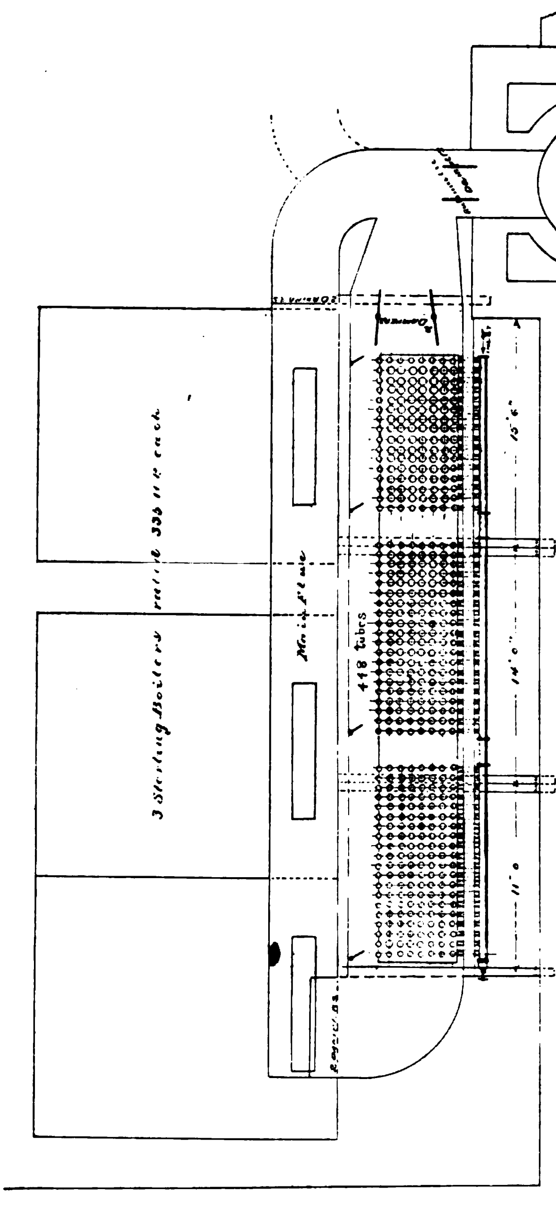
PLATE III. BOILERS AND GREEN FUEL ECONOMIZER (see Figs. e, and g) at Battery No. 5, Armour Packing Co., Kansas City, Mo.

Dimension { Stirling Boilers
Green Fuel Economizer

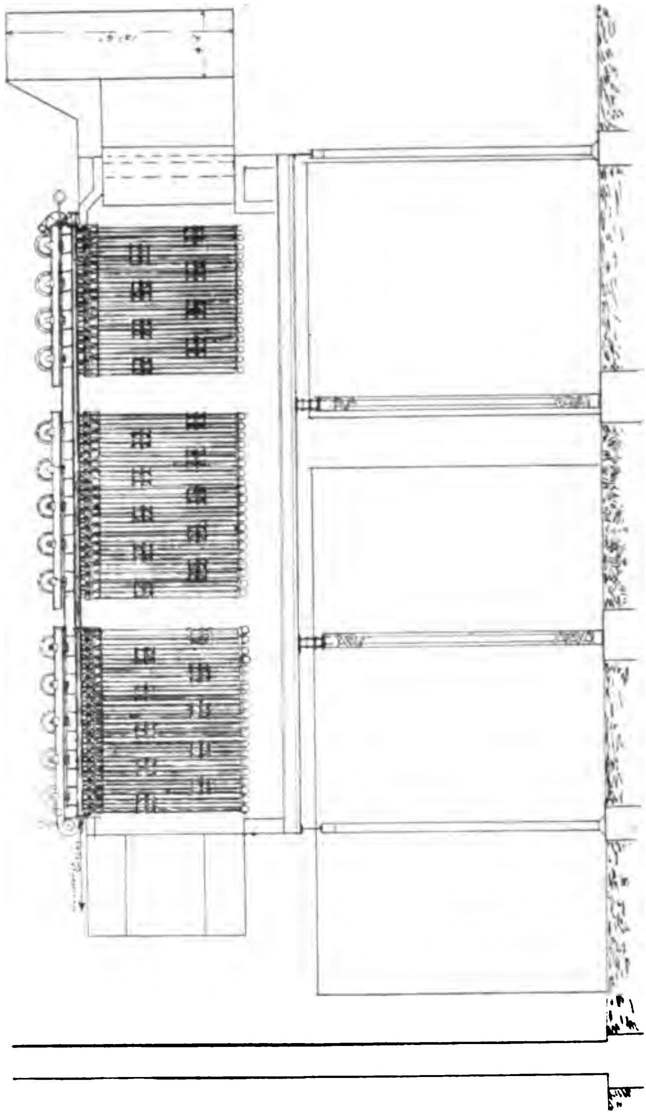
Grate surface of 3 boilers..279 sq. f
Heating surface of 3 boilers..9543 sq. f
Ratio G. S. to H. S..1 : 34.
Number of economizer tubes..44
Heating surface 1 tube..10.69 sq. ft
Heating surface 448 tubes..4749 sq. ft



(Fig. e.) Transverse Section.



(Fig. f.) Horizontal Section. (See page 436.)



(Fig. g.) Vertical Section. (See page 436.)

Kind of Coal		Ardmore, Mo., Bituminous Mine-Run Coal.									
Number of Trial		1.	2.	2.A	3.	3.A	4.	4.A	5.	5.A	6.
Date of Trial 1897	May	14.	15.	15.	17.	17.	18.	18.	19.	19.	20.
Duration of Trial	Hrs.	12.	12.	12.	9 46-60.	9 46-60.	10.	10.	10.	10.	10.
AVERAGES.											
Average Steam Pressure	Lbs.	82.1	84.9		87.0		78.2		83.5		73.6
" Feed Water Temperature, Initial Fahr.	Deg.	72.3	71.2		152.		184.5		176.6		180.3
" " " " Final "	"	72.3	203.4		242.1		265.2		271.1		180.3
" " " " Increase "	"	0.0	132.2		90.1		80.7		94.5		0.0
" Flue Gas " Initial "	"	580.0	537.		562.		535.		508.		523.
" " " " Final "	"	580.0	326.		381.		358.		337.		523.
" " " " Decrease "	"	0.0	211.		181.		177.		171.		0.
" External Air " "	"	....	....		85.2		81.7		83.		84.9
" Draft (water column), Initial	In.	0.68	0.33		0.33		0.16		0.12		0.18
" " " " Final	"	0.68	0.53		0.48		0.39		0.41		0.18
" " " " Decrease	"	0.0	0.20		0.15		0.23		0.29		0.0
" Quality of Steam	%	99.04	99.18		98.62		98.81		98.26		99.21
" Factor of Evaporation		1.182	1.182	1.046	1.100	1.006	1.064	0.9793	1.073	0.9744	1.067
" Horse-Power of Three Boilers	H.-P.	1.167	1201.	1063.	1376.	1258.	1261.	1160.	894.	812.	680.
TOTALS.											
Total Feed Water delivered	Lbs.	412543.	423793.		405200.		413523.		295445.		221688.
" " " actually evaporated	"	408585.	420300.		399600.		408605.		287350.		219920.
" Equivalent evaporated from and at 212° F	"	482920.	496810.	439650.	439560.	402000.	434740.	400110.	308320.	279980.	234670.
" Coal Fired	"	93468.	79200.		51400.		46500.		39150.		37800.
" Combustible Fired	"	75060.	60835.		38190.		35730.		30678.		29920.
" Dry Coal Fired	"	86385.	73200.		47500.		42975.		36181.		34932.
" Refuse from Boilers	"	13485.	15465.		11637.		9026.		6878.		6265.
HOURLY QUANTITIES.											
Actual Evaporation per hr	Lbs	34049.	35025.		43120.		40860.		28735.		21992.
Equiv. " from and at 212° F. "	"	40245.	41400.	36626.	47431.	43380.	43474.	40011.	30832.	27998.	23467.
Coal Fired "	"	7790.	6600.		5546.		4650.		3915.		3780.
Combustible Fired "	"	6255.	5069.		3910.		3573.		3068.		2992.
Dry Coal Fired "	"	7198.	6100.		5126.		4298.		3618.		3493.
EVAPORATION.											
Actual Evap. per pound of coal	Lbs.	4.37	5.31		7.77		8.79		7.34		5.82
Equiv. " " " " " from and at 212° F	"	5.17	6.27	5.55	8.55	7.82	9.32	8.60	7.87	7.15	6.21
" " " " " " Dry " " " " "	"	5.59	6.79	6.01	9.25	8.46	10.12	9.31	8.52	7.77	6.72
Actual Evap. per hour per square foot of Heating Sur.	"	3.57	3.67		4.52		4.28		3.01		2.3
Equiv. " f and at 212°F. " " " " " per hour	"	4.21	4.34	3.84	4.97	4.55	4.55	4.19	3.23	2.93	2.46
Coal Fired per hour " " " " "	"	0.816	0.691	0.691	0.581	0.581	0.487	0.487	0.410	0.410	0.396
" " " " " " " Grate "	"	27.9	23.7		19.9		16.7		14.0		13.
Dry Coal Fired " " " " " " "	"	25.8	21.86		18.36		15.4		12.97		12. 2
Coal to Evaporate 1,000 lbs. of water from and at 212° F	"	193.4	159.5		117.0		106.9		126.9		161.

If the equation for the curve of evaporation is of the form

$$E' = \frac{C}{A R' - 1}$$

then the fuel saving is,

$$W \left\{ \frac{Q-q}{H-q} \right\} \cdot \left\{ \frac{2 A R' - 1}{A R' - 1} \right\}$$

The predictions of formula 12 have been verified in a series of trials on a battery of three Stirling boilers, with an attached Green fuel economizer of 448 tubes, at the Kansas City plant of the Armour Packing Co. The economizer was placed above and behind the boilers in the manner shown in Plate III. Draft is produced by a round brick stack 175 feet high, and 8 feet internal diameter. The capacity of the stack, being somewhat in excess of existing requirements, provides for four additional boilers. The plant had been in operation about two weeks before the trials were undertaken, yet it was subject to considerable losses from air leakage. To this cause, more than any other, may be attributed the departures of the observed results from the curve of evaporation for Ardmor coal under a Stirling boiler of this size and type. See Fig. 164. The summary of results in Table No. 3 shows that tests 1 and 6 were made without the economizer in use, while tests 2, 3, 4 and 5 were made with the flue gases going through the economizer. That portion of the results which would make the trials complete so far as the boilers are concerned is arranged in columns 2 A, 3 A, 4 A, and 5 A.

The curve conforming most nearly to the evidence of the trials 2 A, 3 A, 4 A, and 1 has an equation.

$$E' = \frac{91.12}{0.6879\ R' - 1}$$

Tests 5 and 6 were purposely omitted in the location of this curve, since they evidently fall in the region of the abnormal conditions that were previously defined. The variations of the observed evaporations from the values suggested by the curve stand as evidence of the danger incurred in making one or two trials and drawing extensive conclusions from such limited data. They illustrate the errors to which isolated trials are liable, even with the exercise of all reasonable care, while the group of points, together with the curve, is a good argument for the use of a series of boiler trials in work of this nature.

Analysis of the flue gases shows an air delivery to the furnace per pound of coal varying from 21 lbs. on the 15th day of May to 36 lbs. on the 14th. See Fig. 164. Part of the difference of the fuel used at this plant, with and without the economizer, may be attributed to the heat losses by excess of air. Results as consistent with the theory as at the trials mentioned in the early part of this paper could not be expected under the circumstances.

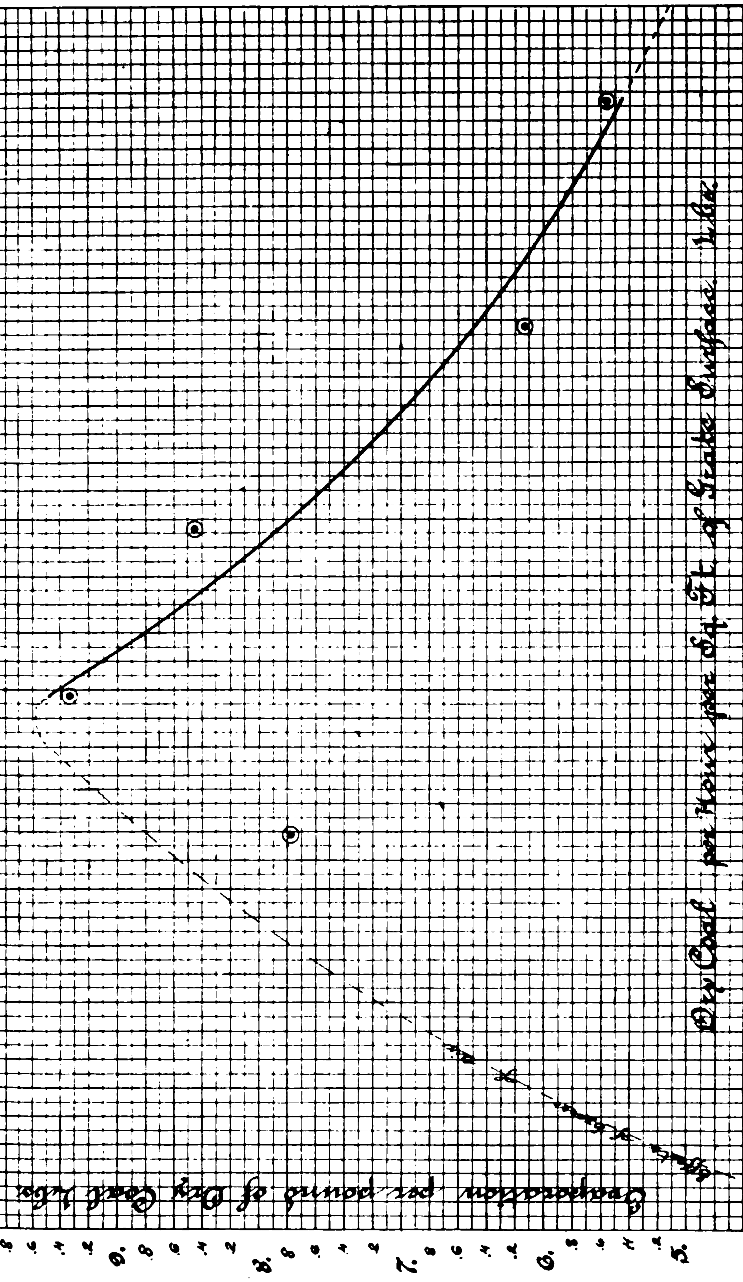


FIG. 164. Evaporation with Ardmor Coal and Stirling Boilers.

TABLE XXIX.

CHEMICAL ANALYSIS OF COALS—PER CENT.

Kind of Coal.	Murphrysboro.	Mission Field.	Glenburn Lump.	Glenburn Screenings.	Ardm Mo
Volatile Matter	36.62	44.50	42.48	39.81	36.
Fixed Carbon	51.28	38.15	41.29	40.3	35.
Sulphur	1.21	2.60	3.87	3.87	5.
Ash	5.42	10.38	14.83	18.20	15.
Moisture	5.47	4.37	1.40	1.60	7.

DIMENSIONS OF STIRLING BOILERS AND ECONOMIZER.

Grate Surface, 3 Boilers	279.	Sq. Ft.
Heating " 3 "	9543.	" "
Ratio H. S. to G. S.	34.2	
Number of Economizer Tubes	448.	
H. S. one tube, Sq. Ft	10.6	
H. S. of Economizer, Sq. Ft	4749.	

TABLE XXX.

ANALYSIS OF FLUE GASES FROM BOILERS OF THE ARMOUR PACKING C KANSAS CITY.

Samples taken.	May 14th, 1897.			May 15th, 1897	
Number of Sample	1	2	3	4	5
CO_2	2.43	4.05	4.07	7.23	7.4
C_2H_4	0.00	0.00	0.00	0.00	0.0
O	14.60	14.92	13.85	10.84	9.2
C O	0.00	0.00	0.00	0.40	1.4
CH_4	3.33	1.05	0.83	2.22	2.3
H	0.00	0.00	0.00	0.00	0.0
N	79.64	79.98	81.25	79.31	79.5

Trial No. 1 shows that the fuel required per 1,000 pounds steam is 193.4 lbs. The same ratio for test No. 2 gives 159.2 of coal. The saving by the use of the economizer is

$$\frac{193.4-159.2}{193.4}=17.5 \text{ per cent.}$$

The saving by formula (7) introducing the feed temperatures

$$100\left\{\frac{172.1-39.3}{1181.8-39.3}\right\}=11.6 \text{ per cent}$$

and the pertinence of the foregoing statements with reference compounded fuel savings becomes apparent.

Comparison of trials 5 and 6 shows a fuel saving at the v light rates of firing of 21.2 per cent, being evidence that a f economizer serves more than its purpose when abnormal con tions exist in the furnace.

Acknowledgment is due to Mr. V. Windett, member of society, for valuable assistance in the experimental work, and the preparation of drawings.

DISCUSSION.

Ir. Summers: I would like to ask how the water measure-
its were made, whether by condensation of the steam or meas-
nents of the feed water.

Ir. Gasche: Those tests were made at different places. The
l water measurements upon the tests of the Stirling boilers
e made by the use of two tanks, about 6 feet in diameter, 8
high. Those tanks were very carefully calibrated by filling
n to a wide and sharp overflow edge from actually weighed
ntities of water, and noting the temperature at the time. The
perature having been taken from time to time during the tests,
knew the actual weight of the water in the tanks. In the case
ne other trials, however, i. e., tests on the tubular boilers, we
l two iron tanks. The only reason for using the wooden
s in the case of the Stirling boilers was on account of the
sical impossibility of weighing such large quantities of water
of filling the tanks as rapidly as required, but in the case of
tubular boiler tests, every pound of the feed water passed over
es. The Stirling boilers developed over 1,300 h. p. It was
rable to test the economizer to observe its influence due to
different ranges of temperature in the feed water; that is, the
erence of the temperature approaching the economizer. For
purpose it was deliberately heated by the use of the open
ter. That water passed through the measuring tank previous
he entrance to the economizer.

Ir. Summers: Was the calorimeter used upon the steam?

Ir. Gasche: Yes, in every case.

Ir. Summers: Diagram 1 is extremely interesting from the fact
three of the curves show practically the same diminishment
he rate of evaporation, that is, the curved lines have practically
same inclination, showing practically the same diminishment
he rate of evaporation. Now in looking at the fourth test or
th sample of coal, it is evident that the rate of evaporation
nges altogether too rapidly with the rate of combustion. I
uld be inclined to look for some reason for this and would
tate to ascribe to the coal alone this variable feature. Per-
s there was clinkering on the grates. Was an analysis made
he ash, or the percentage of ash checked?

Ir. Gasche: Yes, sir.

Ir. Summers: Was complete combustion obtained from that
ple?

Ir. Gasche: In determining the heat value?

Ir. Summers: Yes.

Ir. Gasche: These experimental results, as stated in the pa-
apply to sixteen boiler trials taken at random from a series
60, made for various purposes. The conditions surrounding
trials have been so clearly defined I hope that there can be
mis-conception of the controlling factors. I have stated the
d and construction of the boilers, the distribution of heat-

ing surfaces, and the amount of grate surface. The calorimet measurement of the heat equivalent of the several fuels was attempted. Concerning such heat equivalents, it may be s that they are very nice measurements to undertake, in some ca they are very important; but the question of first importance lates to the actual heating value of the fuel under a given boi under given conditions. It is the question of commercial imp tance, though the engineer may have reasons for using the "to heat equivalent" of a fuel.

Mr. Summers: So that, in making these tests no change made in any of the conditions?

Mr. Gasche: No change had been made for any of the trials cept in the fuels; the boilers were all doing the hard work such is usually required of them in carrying steam. There was no cumulation of scale prior to the tests; they were simply in usual condition.

Mr. Summers: If the coal was not entirely consumed in tests at a rapid rate of combustion, it would account for this f ing off. I agree that the actual heating value of the coal unde boiler is the object sought, but it is equally important that t value be as high as possible, and I believe that every factor sho be investigated that will throw light upon the subject. The sta ment of heating and grate surface with their distribution is sufficient evidence that the coal was either all consumed or t it was properly consumed. These are the factors that determ the commercial features.

Mr. Gasche: If the gentleman will please observe this been clearly defined, viz., the conditions and circumstances s rounding all these experimental results, and it is not the pec arities of a particular boiler, these horizontal and tubular boil to be more explicit.

Mr. Royse: I should like to ask whether the water rate 8,650 lbs. per hour given on page 426 was derived from the cur shown in Fig. 163.

Mr. Gasche: Yes, those figures apply to that.

Mr. Royse: I was unable to get it as 8,650 from the diagr and wish to ask you how you arrived at this result.

Mr. Gasche: The process by which I obtained that fig was of drawing an ordinate at the time indicated, 9:30 A. M., a another at 4:15 P. M., and joining the intersections of these dinates with the curve of feed water weights to give the rate delivering water between those points, and dividing by the ti to get the rate per hour.

Mr. Royse: That is the method I followed, but I did not the same results.

Mr. Gasche: The diagram was purely illustrative and may subject to some error of construction.

Mr. Royse: Were the lines constructed from the data of a of these tests?

Mr. Gasche: This diagram is a graphical log of a boiler trial, t not any of these we have spoken of.

Mr. Royse: Does the line B E represent the drop found in the st?

Mr. Gasche: The drop B E was assumed.

Mr. Royse: Also D O C?

Mr. Gasche: Also D O C.

Mr. Royse: How were the constants in the equations given on ge 434 found?

Mr. Gasche: The constants for the empirical equations of ole No. XXVII were found in this manner:

For each of the several kinds of coal four trials were made. ch of the trials constituted an "observation point" which, presented graphically, would have as an ordinate the evaporation m and at 212 degrees F. per pound of dry coal (exhibited in ole XXVII in the column headed "By observation"), and as an scissa the pounds of dry coal burned per hour per square foot grate. The problem is to find a curve and its equation which ll most nearly conform to the observed results. Application of e method of least squares leads to the derivation of the equan with its empirical constants.

Mr. Windett: I would like to say in answer to a question by . Summers, who asked if the quality of the steam was measured the trials mentioned in Mr. Gasche's paper, that in all the trials it have been made at the South Chicago plant of the Illinois eel Company, there were two throttling calorimeters with a parator used upon steam pipes, one for each boiler being placed out three feet above the boiler in the vertical steam pipe with e sampling pipe horizontal, and observations were taken every een minutes from each calorimeter, and so far as the caloriter's measurements go, there can be little doubt as to the isture in the steam; care was taken in all the other essential ints so far as pyrometer, calibration of scales, delicate ermometers, draught gauges, etc.

Considerably over 180 trials of various coals, boilers and furces have been made recently at the South Works and other nts of the Illinois Steel Company by the author of the even-'s paper and the present speaker. These trials have all been de on the lines indicated by Mr. Gasche's paper, and subjected the mathematical investigation which he offers to obtain the aracteristic curve of evaporation. An analysis of the condins under which these trials were made, using the method of st squares, showed a maximum probable error of 1.4 per cent the evaporation from and at 212° per pound of dry coal. All nditions of operation being satisfactory, a divergence from the ve of evaporation greater than this of any single trial would be e to the handling of the fire. The average variation of the rets of the individual trials from the curves of evaporation of ese trials was 1.8 per cent, which gives as the average error in

the results due to methods of firing as 0.4 per cent, or about 0.03 of a pound of water evaporated from and at 212° per pound of dry coal. Thus problems of steam making and boiler house design can be attacked with an assurance of correctness which would be hazardous when based on isolated trials of even many coals or appliances, and a method of searching investigation is at hand with which one may examine the claims of the various devices to save fuel bills.

A study of the code offered by the A. S. M. E. for the proper conduct of boiler trials shows that the committee presenting the set of rules forming it realized the necessity of a perfect uniformity of working conditions, recommending especially the partial closure of the steam valve on the boiler to maintain a constant pressure during that trying period for the boiler when the fire is pulled off the grate and the boiler cooled down by the inrush of air. In the presence of this latter disaster, it appears a little like irony to suggest maintaining the steam pressure, whose variations, if there were any, are provided for by using the "factor of evaporation," and should there occur a variation in the steam pressure unobserved so great as 5 pounds per sq. inch, the results are in error to the extent of one in 1,100 parts, whereas Mr. Gasche shows the error due to letting the fire die down at the close to be 1.21 lbs. of water, or 17½ per cent. Yet the "code of rules" provides that this effect shall be imposed upon the trial at start and finish, by the extraordinary procedure of hauling the fire at the start and kindling a new one with wood and fresh coal, meanwhile cooling off the boiler and setting by an inrush of cold air, and then cooling it off during the close, and you are to consider the conditions of the trial as regular and uniform. Is it more unreasonable to dash a pail of ice water on an athlete before and after running a 220 yards' dash?

In the alternative method permitted by the A. S. M. E. of a flying start, the only source of error is the error in the difference of the estimates of the amount of coal on the grates at the start and finish. With experienced men this ought not to exceed 25 lbs. or 50 lbs. with heavy fires and heavy rates of combustion, using large quantities of coal.

An objection has been urged by engineers in the city to the results being given as evaporation per pound of *dry coal* on the ground that the consumer has to pay for the moisture in the coal and wants to know what the coal, as he buys it, is capable of doing. But how is one to discriminate between this "purchased" moisture and that which comes down on the coal as it stands in the car or wagon or in the pile between the time of change of ownership and of use, and there is the water which the misguided fireman is sometimes allowed to throw on his coal on the plea that it burns better. Even when protected and under cover the coal will dry out some of the original moisture, so the chances of getting the coal with the purchased moisture are very slim.

Evidence is given in the Kansas City trials that automatic kers have not reached that state of development where they do waste in the furnace a part of the money they save in fire-n's wages, on account of the liability of the fire burning into es. In view of this the flue gas analyses are interesting, show-an excess of oxygen and unconsumed coal.

Ir. Gasche: This graphical log is of a certain boiler trial er than any trials of which experimental evidence is given in paper. By evaporation per pound coal derived from trial of ch this graphical log was obtained, we divided the total ount of water by the total amount of coal, because the observa-ns during the operation of the trial gave evidence of which te No. 2 shows that the conditions were almost exactly uniform; ice, we could divide the total weight of water with the total ght of coal and assume by that very division the rate of ivery which had been constant.

Ir. Summers: If your presentation is true, it shows, does it , that the evaporation was almost constant from 8:15, the time starting up, to the point of deviation, about 4:45.

Ir. Gasche: Almost a constant rate.

Ir. Summers: Now that being so, you have a true measure of evaporation per hour.

Ir. Gasche: Undoubtedly, you would obtain an average poration per pound of coal.

The process of getting the evaporation by dividing the total ght of water by the total weight of coal would be the same as division of the rate indicated by the line OE by the rate wn by the line OG. It is the division which has been con-ered allowable in the calculation of results of trials made in the inary manner. The accuracy of the quotient is questioned for sons which have been enumerated.

Ir. Summers: Our President, I think, was one of the first to this method in testing water works. Everyone knows the iculty encountered in judging the condition of the fire. If O E was taken, it would give you an entirely different evapo-on from that shown as the true one, provided the graphical resentation is correct; it would simply be base assumption to ide O E by line O F to get the average evaporation.

Ir. Gasche: This assumption was taken in order to show the l amount of water and the total amount of coal.

Ir. Summers: The only possible chance for error would be in surements where the graphical representation is used. I k twenty-four hours is the accepted standard for tests, and certainly provides against errors.

Ir. Gasche: It is a very difficult thing to make tests of that ation.

Ir. Royse: From the diagram shown in Fig. 163 I have calcu-d the water rate between 9:30 and 4:15. The total water at 5 was 61,000 pounds, at 9:30 7,500; this gives a water rate of

7,920 pounds per hour, and 7,920 divided by the assumed coal rate there of 1,250, gives 6.3 lbs. as the water per pound of coal instead of 6.9 lbs., as given on page 426 of the paper.

This shows the difference between the evaporation per pound of coal found by the method recommended, and that found by dividing totals, to be .6 lb. instead of 1.2 lbs. as given on page 4.

Mr. Monroe: I was discussing the paper sub rosa with Mr. Windett in regard to Fig. 163 of the diagram. As Mr. Gasche said, this diagram shows the results of only one test made with a flying start, and the lines and estimates for the corresponding test with the standard start are purely assumptions, and do not represent any positive figures at all. Mr. Gasche's assumption is that the rate of feed water drops a certain amount, and the rate of coal drops a certain different amount, when the fires are burned down, and I was saying to Mr. Windett that it is simply an erroneous assumption. They would not drop in any such way as is indicated. Of course, the rate of consumption of both will drop off, but the decrease will be much more nearly proportional than indicated on Mr. Gasche's assumed diagram. Now the assumption of the American society standard method is, that the drop off is practically proportionate and if it is there is no difference in the evaporative figures obtained.

Mr. Winger: It seems to me it would be much safer to carry on the trial from a flying start to a finish without change of rates, and then you are absolutely certain you are making no error; if the trial is made long enough the rates will be accurately determined and no one can question them; then there will not be any such assumptions, and I think it would be much safer.

Mr. Windett: Inasmuch as there is a lowering of rates which Mr. Winger admits there would be some error—that is enough to condemn the whole thing, because you cannot say whether the variation of results is proportional or disproportional; you cannot say anything about it except you know there is a difference, which I think is sufficient to condemn it, the error being there and yet one cannot say whether it is + or — nor the extent of it.

Mr. Monroe: I do not especially wish to defend the standard method of the American society, and I think that in each case it is a matter of practical experience whether the "standard" or the "alternate" method should be used, and depends largely upon local requirements and the purposes for which the test is made—all of which must be taken into consideration; and, as the gentleman who last spoke remarked, if you make the test long enough all errors due to the start and finish are practically eradicated. But it must be added that any errors due to the start and finish by the "standard" method so far as evaporative efficiency is concerned are only due to the losses from radiation, etc., from the boiler while heating up or cooling down. If properly conducted these cannot be very great, and certainly not greater than the errors due to judging a fire by the "running" start and stop.

XIV.

INTERNAL HYDROSTATIC PRESSURE IN MASONRY, WITH ESPECIAL REFERENCE TO MASONRY DAMS.

By ARNOLD EMIL BROENNIMAN and HARRY HURSON ROSS.

Read August 4th, 1897.

ne question of the possible existence of internal pressures in onry construction, and especially in masonry dams has, during last few years, received careful consideration by many promit engineers. That this question should receive careful atten- is evident from a consideration of the vital importance which ars to the interests of millions of people who, through a lack ne most careful consideration of their welfare, may be placed position where their properties and even their lives become angered.

the generally accepted theory, in the design of masonry s, no consideration is taken of an internal water pressure. In work on "Masonry Dams," Mr. Wegman assumes that the onry is impervious to water. This assumption, which therefore udes the consideration of internal water pressure, has not, ever, received the approval of other prominent engineers. In e of the papers read before the American Society of Civil ineers it has been controverted. In Vol. 34 of the Transacs of this society, Mr. Van Buren, on page 494, says: "In addi- to the usual forces assumed to act upon the dam, there will onsidered a water pressure on the base under full head. This e is usually ignored in designing the section under the suppon that the masonry can be either made practically watert or drained in such a way as to relieve this pressure. It is, ertheless, always one of the probable dangers to which such m is exposed." He further adds that "in the opinion of the or a water pressure on the base of high masonry dams should ys be considered in the design, i. e., the section should be e large enough to provide for a water pressure at all base ls."

ne failure of the Bouzey dam in France is cited as showing the danger of failure by the action of the water pressure on base of the dam is neither imaginary nor remote. Mr. Van en says: "The section of this dam was wholly inadequate to ish the necessary stability with a water pressure on the base. 882, 442 feet of this dam moved down stream, without tilting, s to form a bulge concave with the reservoir and having a ed sine of about 1¼ feet and badly cracking the masonry at bends. This year (1895), notwithstanding expensive repairs lving a heavy reinforcement at the toe and a deep cut-off

wall at the heel, it was completely destroyed, resulting in the loss of 150 lives. An examination of the section of this dam shows that no provision was made in the design for a water pressure on the base. It is not at all improbable that the equally disastrous failure of the Habra dam in Algiers, in 1881, resulted from an inadequacy of the section." Mr. Wegman, in the discussion of the above paper, says: "The failure of the Bouzey dam is the only case where an upward pressure under the base of the wall is likely to have been the cause of the disaster. In all probability this pressure would not have occurred to any extent if the whole dam had been founded on the solid rock upon which the guard wall was built."

It is evident that if the foundation of a large masonry dam is perfectly rigid, with no uneven settlement in the dam itself, that the lowest joint can be made as impervious to water as any of the other joints. This ideal condition is, however, not always found in practice, and this led to the extensive discussion of the paper above mentioned. If the foundation is of such nature that the water penetrates it readily, there will naturally exist some hydrostatic pressure, but how this pressure will vary is not known. It has been proposed to assume this pressure as being equally distributed over the entire base, but that this assumption is in excess of the actual amount is quite evident. Not considering at present how the pressure varies between the extreme points of the base of the dam, it will be admitted that it must be a maximum at the heel and zero at the toe. If, on the other hand, the foundation be impervious to water in the same degree as the masonry itself, the direct action of the water is not so readily seen.

Another point of discussion was in regard to the formation and effect of cracks, Mr. Van Buren maintaining that it was impossible to construct a dam which is practically water tight and free from cracks and fissures. Mr. Wegman, on the other hand, maintained that this had practically been accomplished in the construction of two dams in the Croton watersheds. These dams, the Sodom dam (98 feet high above the foundation) and the Titicus dam (135 feet above foundations) are perfectly dry in clear weather, and only in damp weather do moist spots appear on the walls, and that with the exception of a small hair crack there is absolutely no crack to be found in the two cases mentioned. That the disappearance of moisture on the walls of the dam during dry weather and its reappearance during damp weather can be satisfactorily accounted for by the increased evaporation during the dry weather seems evident. The flow of the water through the dam can be only a small amount, and the evaporation may take place at a rate such that no signs of dampness occur. Why it should appear in wet weather and again disappear during the dry weather cannot, it seems, be explained in any other way. It follows, then, that even in dams, which we

y assume are constructed as perfectly as workmanship will ow, water will force its way into the pores of the stone and ss through, appearing again on the farther side. Might not s fact alone produce effects within the dam which were not nsidered in the original design? With the existence of cracks d fissures the stability of the structure is evidently decreased. e water entering these crevices will naturally exert a pressure thin and will tend to decrease this stability by bringing into ion the hydrostatic water pressure which had been neglected the design.

Admitting that it will be possible to construct a dam whose indation will be as impenetrable to water as the body of the m itself and that this dam can be made practically free from icks and fissures, what is the effect of the water which perco- es through the pores of the stones? This is the problem which e writers have tried to solve. If the assumption of the water essure on the base of the dam is correct, then the design as sub- tted by Mr. Van Buren is admittedly correct. Can this pressure furnished by any other means than through "the base of a ll founded on a rock, having numerous seams, containing water der a head, the flow from which is not carried off by drains?"

Says Mr. Francis: "Assuming that the work is as well done it can be, that is, that all stones are perfectly bedded in the ortar and that all joints are solidly filled with concrete or mortar, uld the upward pressure from the seams be communicated to e entire base of the wall?" "This involves the question as to ether the pressure of water can be communicated through the pillary channels of the mortar." Mr. Francis then made a series experiments on the transmission of pressure through hydraulic ment, in proportion of cement, one, sharp sand, two (Transac- ons American Society Civil Engineers, Vol. 19, p. 147). His periments show quite conclusively that hydraulic pressure can transmitted through ordinary cement mortar.

Says Mr. Wegman, in the discussion of the preceding paper: Vhat effect will the water penetrating the wall exert upon its bility? So long as it passes through the wall and not under it, idently none (leaving the deterioration of the masonry out of nsideration), for the water penetrating through any small chan- l will exert practically the same pressure upwards as down- rds. This conclusion is verified by the experience with the abra dam in Algiers. When the water was first let into the servoir, the dam is said to have presented the appearance of a gantic filter, so great was the leakage through it, and yet this ct does not seem to have affected its stability." That Mr. egman is justified in the statement that the upward pressure of ter is practically the same as the downward pressure is evident ien only a small channel is taken into consideration, but that is may not be the case when the dam as a whole is considered ll be shown later. Furthermore, whether his conclusions are

verified by the experience with the Habra dam is doubtful. M
not the stability of this dam have been greatly decreased with
being observable? Mr. Wegman further adds: "This loss
water diminished rapidly owing to the channels of leakage bec
ing clogged. The experience with the high masonry dams b
abroad has shown, however, that with proper care and precaut
such walls, formed of ordinary rubble masonry, can be built
water tight that only a slight dampness is noticed on the do
stream face. Taking this well established fact in connection w
the experiments of Mr. Francis, I should conclude that the wa
can penetrate only a short distance with its full hydrostatic pr
sure into the masonry, and that if it passes through a well bu
dam, it loses its force and simply goes through in a capill
manner."

The effect of the assumption of a water pressure, over the ent
base of the dam, of full hydrostatic pressure is to materia
increase the size of the cross section and consequently the amo
of masonry. This is fully shown in the cross-sections of Fig. 1

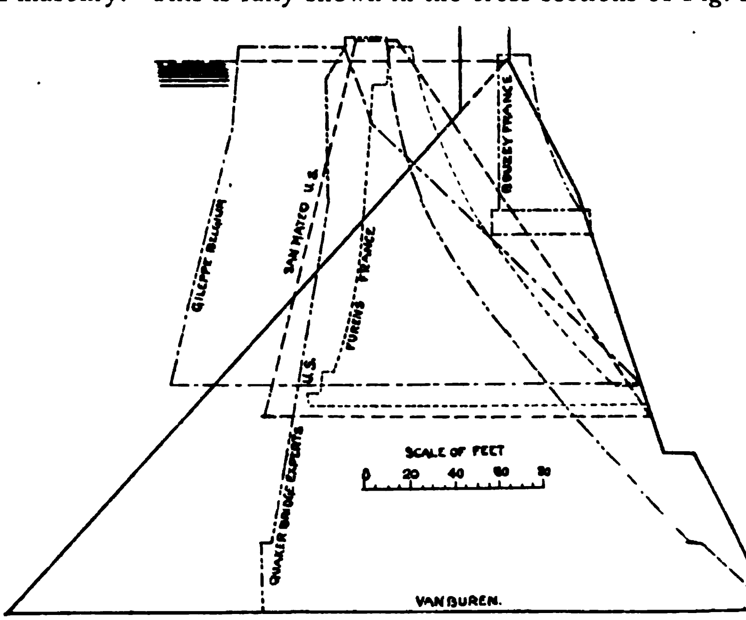


FIG. 165.

taken from Van Buren's article in Vol. 34, T. A. S. C. E., abo
referred to. "According to this figure, the profile for the propos
Quaker Bridge dam, designed by a board of experts, would ha
to be increased about 65 per cent in area to satisfy the autho
views."

Says Mr. Wegman in Vol. 19, T. A. S. C. E.: "I know of b
one modern dam which has been designed on the supposition th

water pressure from the reservoir might extend under the
le base, viz., the Gileppe dam, built in Belgium in 1870 to
. This dam contains an excess of 75 per cent of masonry
that which is placed in modern French dams of the same
ht."

e see from this the importance of the assumption, and the
rence in the resulting profiles of the two cases, namely, one
nich the water pressure is assumed to act, and the other in
h it is omitted.

r. Kenneth Allen (T. A. S. C. E., Vol. 34) "would suggest as-
ng a certain proportion, say 10, 20 or 30 per cent of the up-
pressure acting on the entire section, depending on the
acter of the masonry employed, and, in the case of the base,
ne bed rock upon which it is built." He further says: "Ad-
ng that a certain amount of percolation obtains with an un-
nished static head, yet the extreme proportion of such areas
rcolation to the entire horizontal section of the dam must be
small in cement masonry. So that, while it is safe to assume
tain amount of upward pressure, as, indeed, will probably ob-
yet this can never act on more than a small fraction of the

e have thus three recommendations offered us, namely, (1)
the pressure be entirely neglected; (2) that the full pressure
the whole area be taken into consideration; and (3) that only
tain percentage (10, 20 or 30 per cent) of the upward pres-
acting upon the entire section be taken into consideration.

e writers, with the apparatus at their command, have tried
certain whether either of the two extremes suggested or
ner the happy medium is the most satisfactory to adopt.
problem which therefore presented itself was this: Does the
which percolates through the masonry of the dam exert any
ure, and if so, how is it exerted, and in what manner does it
from point to point, or does the water merely pass through
ock in a "capillary manner?" We assume, as has been
l before, that the foundation is of the same quality and den-
s the remainder of the dam, and that no cracks or fissures
within the dam or foundation.

th this question before us, our apparatus was arranged in
a manner that the results may be, with so large an element
tainty as possible, directly comparable to actual conditions.

APPARATUS.

arranging the apparatus to ascertain the variation of pres-
within any given stone, several methods suggested them-
. The main items of consideration were, first, that it was
utely necessary to know that the water followed its designated
while flowing through the stone; second, that no cracks or
es of any kind should interfere with the flowing water; and,
that no water pressure should exist on any other faces of
one than the face intended for that purpose.

The experiments above referred to, namely, those of Francis, show the precaution necessary in the arrangement o apparatus. The arrangement of Mr. Francis' apparatus is sh in the accompanying fi 166. It consisted essent of an iron cylinder A an interior cylinder B. were filled with cemer to a line as shown. W pressure was furni through the feed pip into the chamber above cement. Pipes E and I tended through the iron tom to the cement, an these were attached gauges as shown, to re the interior pressures. small crack existed in tube A near the point G will be noted that the ce was entirely excluded the air, and the wate longer flowed after saturation of the cement had once se That the small crack on the side of the tube materially affe the result of the experiment is very evident. If the amour water flowing through the stone had been zero, as it should been had no crack existed, there is no possible reason why pressures recorded by the lower gauges should not have the same as that on the gauge of the feed pipe.

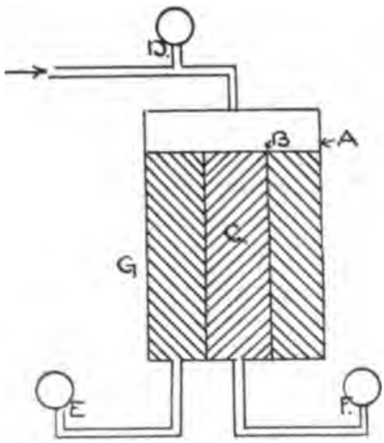


Fig. 166.

In the experiments made by the writers, the apparatus was of such a character that one side of the stone was ope water pressure while the opposite side was open to the air. remaining four sides were made water tight in various w depending whether building stones or cement mixtures experimented upon. In the case of the building stones, a lay neat Portland cement was put around these four sides. cement, as will be shown later, is practically water tight, hence, could be used to good advantage in this connection. thickness of this coating was about ½ inch. This precau prevented any possible side leakage into the stone and henc sured safety against the interference with the pressures recor and forced the water to follow its designated path.

In the case of the various cement mixtures under experime was deemed advisable to adopt a different method. Wro iron pipes were used, and these were filled with the cer mixtures. It was both easier to handle the material with arrangement, and it also furnished a direct comparison with experiments on building stones.

course, the possibility also presented itself, just as in the f Mr. Francis' experiment, that the water might find a pass- etween the cement and the inside of the pipe. After the xperiment with neat Portland cement this was, however, not to be the case, for in the seven weeks during which this vas under pressure no water made its appearance on the xposed to the air. If any passage for the water had existed en the cement and the inside of the pipe, the water would forced its way through this and would have been in an it such as to be perceptible on the dry surface of the ce- Since this remained perfectly dry, we are safe to conclude ie water could have no other mode of passage than through ment itself, though in this special case the density of the al prevented this. It serves here, however, for the purpose wing that the results obtained from the cement mixtures ie results obtained from the building stones are directly rable since the methods of experimentation place the same tions on the flow of the water in each case. Another possi- erference with the flow of the water would have been occa- had a small leakage around the small piezometer tubes, ed in the cement, taken place. With the precautions taken, ossibility of this interference, however, disappears. This ecome more evident when a description of the method of ig the tubes against any possible leakage is given.

how more clearly the exact appearance and use of the ap s, the following figures together with an explanation of the iave been inserted.

apparatus used was of two kinds as already mentioned; iat used for testing building stones, and, second, that used ting cement mixtures.

apparatus for stone is shown in Plates IV and V. Fig. 1 of late shows a general view of the box, into which the stone ed. Fig. 1, Plate IV, shows the end at which the pressure is d to the stone, and Fig. 1, Plate V, shows the open end of one where gauges for recording the internal pressures are ed. Fig 2, Plate IV, shows a longitudinal section of the box one taken through the center, and Fig. 2, Plate V, shows a m of the plan by which the holes were drilled. These holes bout ¾ inch in diameter and were drilled into one face of one to varying depths. Iron tubes ⅜ inch in diameter were nserted and neat Portland cement rammed around them ement being used because it was found upon experiment to ctically impervious to water). After the cement had thor- set a coating about ½ inch in thickness, of the same cement, it on the four sides of the stone perpendicular to the face ed to the air. The stone was then placed in the box, the bolted down, and the clamps, as shown in the figure, were ned up. The small iron tubes were then connected to ry gauges by rubber tubes. After all was ready the pres-

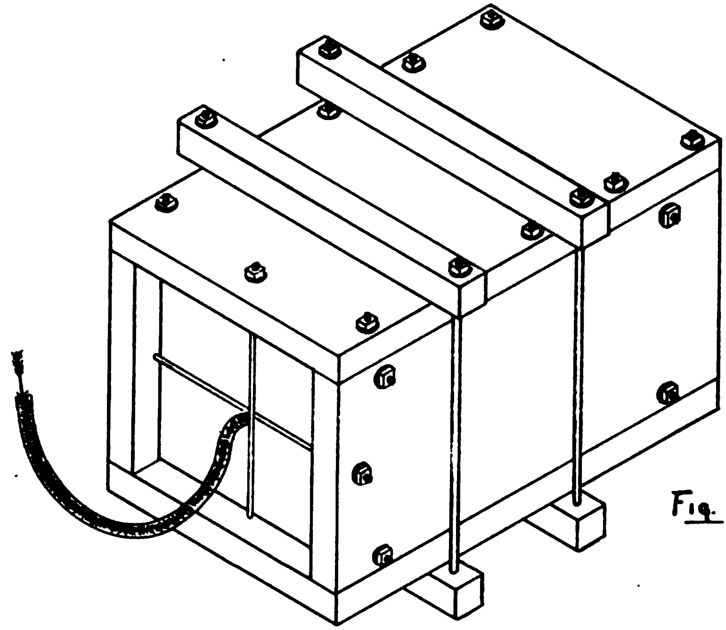


Fig. 1

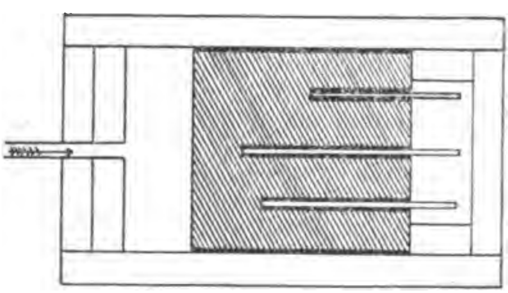


Fig. 2

PLATE IV.

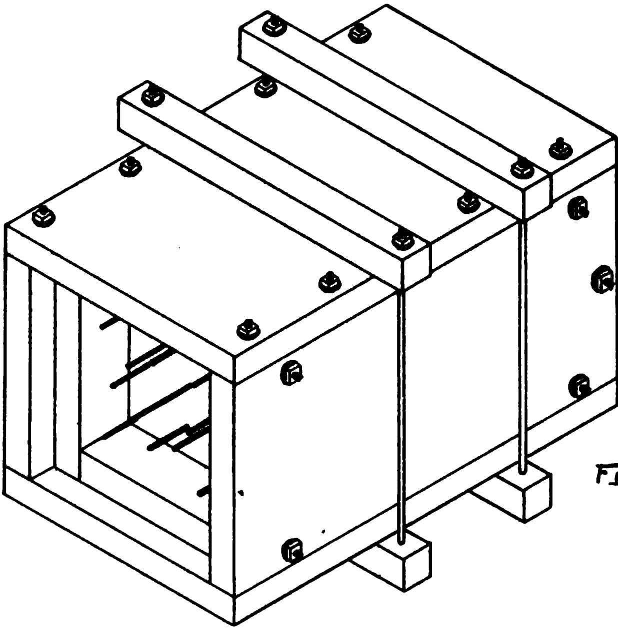


Fig. 1

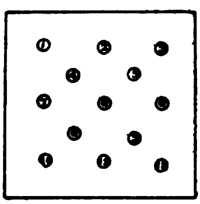


Fig. 2.

No.	Oölitic Limestone		Calcareous Sandstone	
	Depth Hole	Depth Stone	Depth Hole	Depth Stone
1	6.38	8.87	5.25	7.50
2	8.31	4.44	6.50	6.25
3	7.25	6.50	7.75	5.00
4	8.75	5.00	5.12	7.63
5	10.50	3.25	6.25	6.50
6	10.89	2.86	9.12	3.63
7	8.75	5.00	5.88	6.88
8	8.25	10.50	5.38	7.88
9	4.50	9.25	3.62	9.13
10	6.50	7.25	8.00	4.75
11	4.05	9.70	4.50	8.25
12	6.25	7.50	7.38	5.38
13	2.37	11.38	4.38	8.38

PLATE V.

sure was applied and the readings of the mercury gauges at frequent intervals. This was continued until the gauge ings had arrived at a maximum in the various gauges. Th ond type of apparatus was used for the cement mixtures, an constructed from wrought iron pipes. It seems an establ fact that cements expand to some extent when allowed t hence it was thought that instead of using a box, as was with the stone, an iron pipe could be used. This was fillec the cement mixture, and after placing a cap on one end a co tion with the water main was made. In this arrangemer water which passed through the cement was therefore subj to the same conditions as was the stones in the box, and i used in all the tests with cements. Three different sizes of were used and are shown in section on Plate VI.

The first was 4 inches in diameter and 22 inches long, an used for the tests upon neat cements.

The second pipe was 6 inches in diameter and 22.5 inches and was used for tests of mixtures of cement and sand of diff proportions.

The third pipe was 3 inches in diameter and 60 inches lon was used for tests of various cement and sand mixtures. difference of the two latter consisted essentially in that we able to find how the pressures varied in a greater length ment in the last case than in the preceding.

All the pipes were prepared in a similar manner, as fol Holes of small diameter were first drilled into the pipe at re intervals, along a line parallel to the axis of the pipe. Smal tubes were placed in these holes and held in such a positio means of wooden framework, that the lower ends of the were in line along the center of the pipe. The cap was the on one end of the pipe and some loose sand placed in the the object of which was to bring the end of cement perpend to the axis of the pipe. The mixture of cement or of cemer sand was then placed in the pipe, thoroughly rammed, an lowed to set. The framework, holdin small piezometer tubes in position, wa moved and buttons of neat Portland ce placed around the bottoms of the tubes. these had set a coating of paraffine wa over the cement to prevent any evaporatio thus secure a perfectly water tight joint.

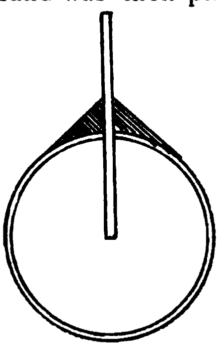


FIG. 167.

These buttons of cement, Fig. 167, used for the purpose, as has been stat prevent any leakage around the small t and were found very efficient. Trouble w first experienced in finding some suitabl terial for this purpose. The first plan w cast molten lead around them, but this di give satisfaction. Molten sulphur was

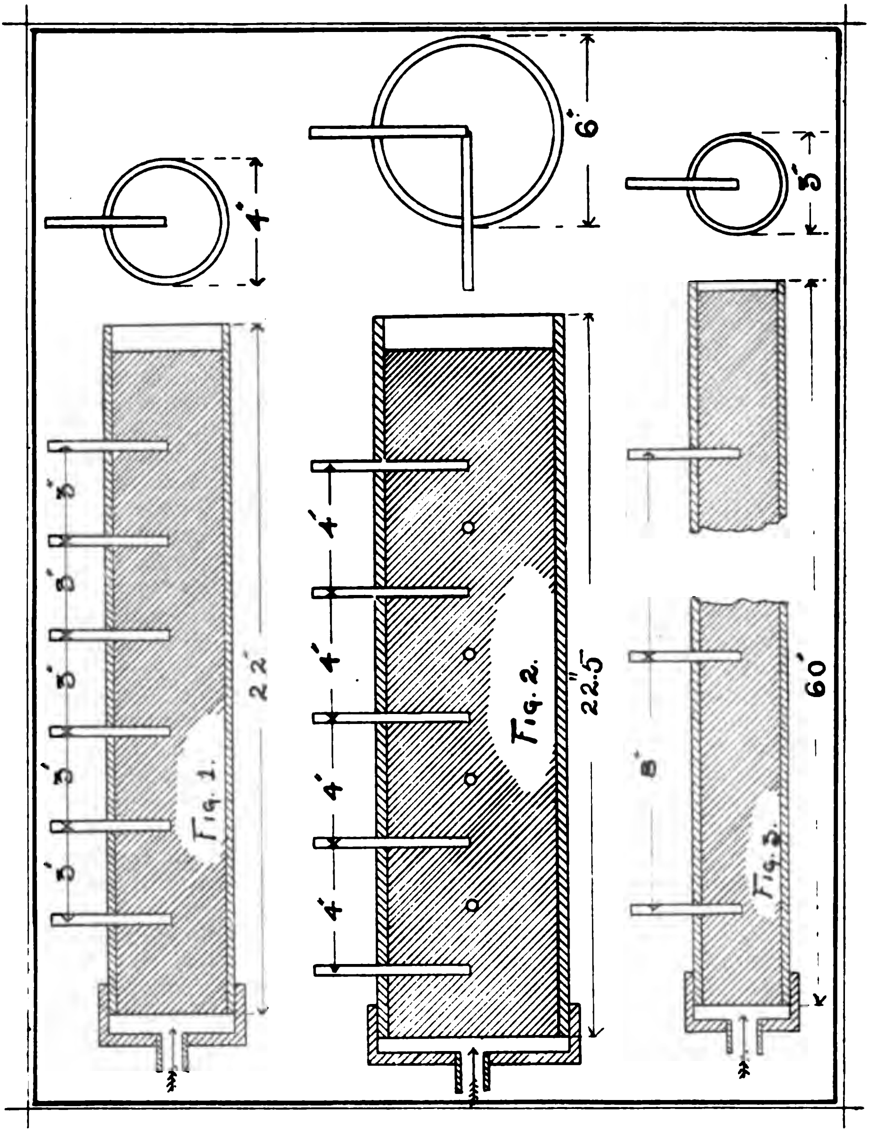


PLATE VI.

tried in place of lead. This gave very fair results and was qu satisfactory, but it was found that the best results were obtai by the use of neat Portland cement. This cement, as some of later experiments will show, may be considered practically wa tight, and this fact, together with the ease of handling the cem over the other materials, led to the adoption of this arrangeme

Before the cement mixture in the pipe was subjected to pr sure, the loose sand used to obtain an even bearing for the m ture was carefully removed, thus directly exposing the full f to the water pressure.

RESULTS OF EXPERIMENTS.

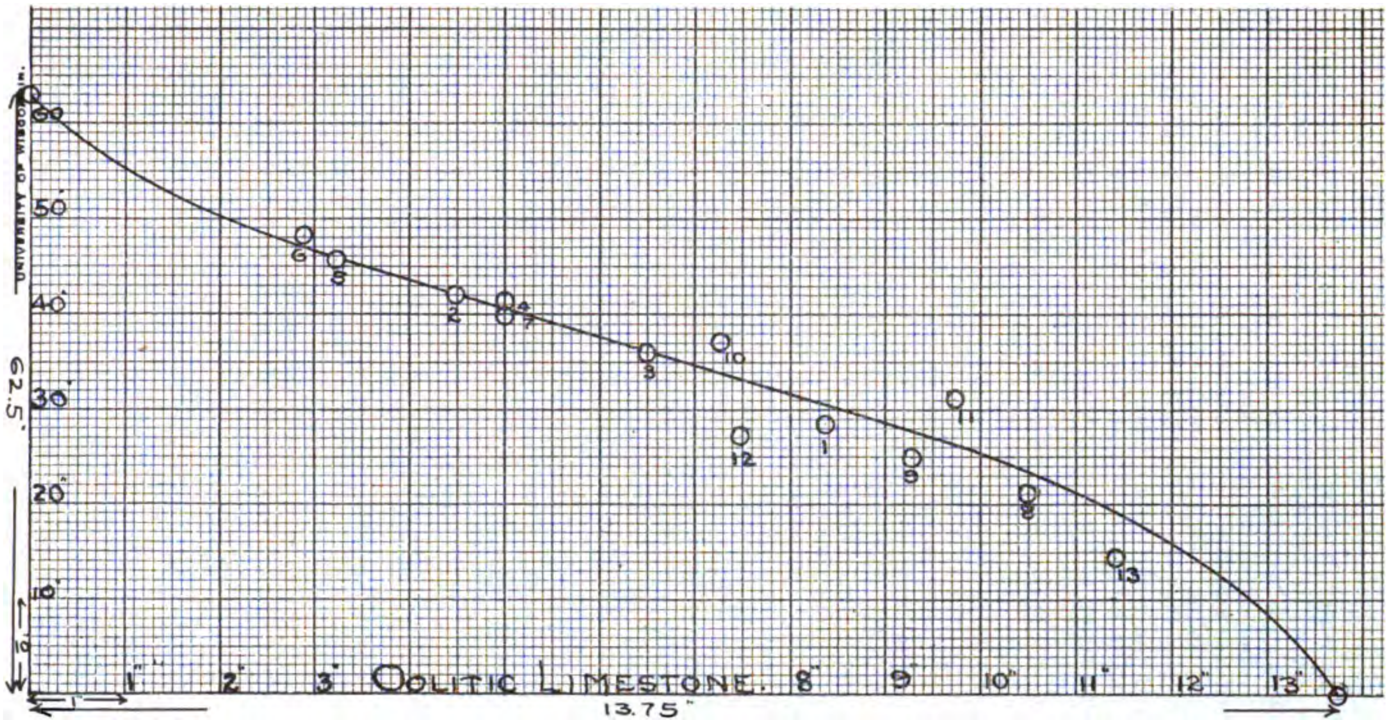
I. Oolitic Limestone.

The results of the experiments are best shown by the follow sets of curves:

Curve in Fig. 168 represents pressures in stone on March 30, A. M., 16 hours after the pressure was first applied. This cu does not register quite the maximum pressure obtained. several days previous to taking this reading trouble was perienced in keeping the head of water constant. It took so time to locate the trouble, and in the meantime the water allowed to flow through the stone. The filtering of the water, the effect which this produced upon the recorded pressures in mercury gauges, showed itself in the meantime, but this will discussed more fully hereafter. The water, it may here be stat was drawn from a neighboring lake and contained considera matter which clogged the pores of the stone. During the time which the water pressure was allowed to act, a mercury gauge h been connected to the tube running into the stone to the great depth (No. 6 on the plate). This was the only one that had be attached at the start, and frequent readings were taken on The maximum reading taken was 52 inches (of mercury), but t reading was not recorded because the rest of the gauges had been attached. If the readings of the other gauges, as shown curve Fig. 168, were increased in the same ratio and the result curve plotted, then this would probably represent the act maximum pressures obtained.

To remove any of the material which may have collected on surface of the stone, it was decided to clean the surface. T was done in as thorough a manner as possible, using first a poin chisel to scratch the surface, and after this an abundant wash w water and a sharp broom. The face was almost entirely clear of the matter which had accumulated, but that this was absolutely the case is shown by a comparison of the maxim reading on curve Fig. 168 with the actual maximum abo mentioned. It is, however, the maximum series obtained on t stone and represents the actual maximum very closely.

A difficulty was also occasioned by the fact that the mercury the gauges did not rise at the same rate. It could not be pected that it should rise evenly in each of the various gaug



Abscissa--Thickness of stone. FIG. 168. Ordinate—Pressure--inches of mercury.

since the water in some cases had to travel through considerab
more stone to reach some of the tubes than others, but t
difficulty was occasioned by the fact that some of the gaug
whose tubes extended approximately the same depth in the sto
did not rise equally. For instance, Nos. 1 and 12 were alwa
slow in rising. This becomes quite apparent on the curve
In placing the cement around the piezometer tubes some of
entered the small tubes from the bottom due to the rammir
This had to be removed from the interior of the tubes and t
unequal rising of the mercury is, no doubt, due to the fact that
removing this a trifle more or less than necessary may have be
removed. Those from which more was taken out consequent
had a larger well from which to draw their water, and this caus
the mercury in the respective gauges to rise faster than in t
others. Probably a thin layer of cement remained in the botto
of some which would add additional resistance for the water
reaching the tube, and hence retard the flow. The readings f
curve Fig. 168 were taken after tubes Nos. 1 and 12 had reach
their maximum. The pressure on the face of the stone was 62
inches of mercury. This determines one point of the curv
while another is determined at the open end of the stone whe
the pressure is atmospheric, or zero as used in this case. Th
curve was drawn to fit the points as closely as possible. Hol
Nos. 4 and 7 were accidentally bored to the same depth, and
furnished a check to some extent to the readings.

Curve Fig. 169 was drawn from a series of readings taken at
P. M., March 30, 5 hours after curve Fig. 168 had been taken, ar
shows a considerable diminution of pressure. This diminution
is produced by a deposition upon the face of the rock of sol
matter carried by the water, thus clogging the pores and cons
quently diminishing the flow of the water by offering addition
resistance to the same. This is very clearly shown in some
the following curves.

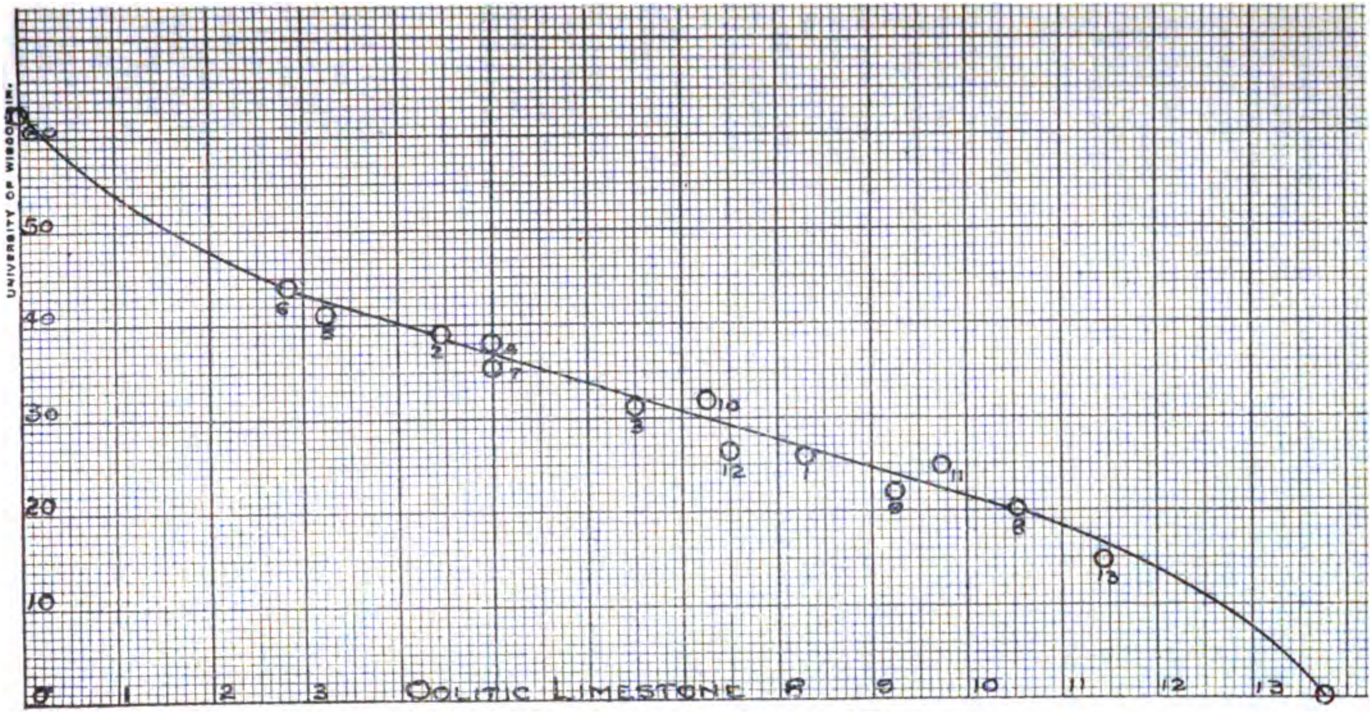
Curve Fig. 170, taken at 2 P. M., March 31, 24 hours after cur
169, shows a continued diminution of pressure.

Curve Fig. 171, taken at 2 P. M., April 1, 24 hours after cur
170, also shows a continued diminution.

Curve Fig. 172 was taken at 2 P. M., April 2, 24 hours after cur
curve 171.

On Fig. 173 is reproduced this series of five readings. Th
makes it very plain how the clogging of the pores caused a redu
tion of pressure. It will be noticed that the pressures in th
gauges near the pressure face of the stone drop at a more rap
rate than the others do, probably due to the fact that the sedime
is nearly entirely extracted before reaching those tubes whic
are not placed in the stone to such a depth.

A considerable number of readings were taken on the ston
but those given will probably suffice to show the variation ar
change of pressures. It will also be noticed that as the pressu



UNIVERSITY OF WISCONSIN.
60
50
40
30
20
10
0
1
2
3
8
9
10
11
12
13
OOLITIC LIMESTONE

FIG. 169.

on the stone is continued the readings on the various gauges fall closer to an even curve. The pressures become settled as the process continues; Nos. 1 and 12, however, show their retarded condition, as has been explained before, although they also come closer to the even curve with the lapse of time.

Curves Figs. 174-175 are plotted 9from the rates at which the pressures decrease at any given point in the stone. They will naturally fall on a straight line, the filtration being almost uniform. They continue for a period of 10 days and show the change of pressures during these days.

II. Calcareous Sandstone.

To extend the scope of the experiments, a second stone was placed in the apparatus in exactly the same manner as the first and put under pressure. The stone was a mixture of limestone and sandstone. It was taken from the Madison quarry, and was fresh from the quarry when used.

The general method described in the preceding test was used. Holes were drilled into the stone to various depths, but owing to the brittleness of the material the deepest hole could not be driven to as great a distance as in the preceding case. The size of the stone was 12.5″x12.5″x12.75″, the longer dimension being placed perpendicular to the pressure face. The arrangement and depth of holes is shown in Plate V.

Curve Fig. 176 shows the maximum pressures obtained on this stone, and was had 2 hours and 45 minutes after the pressure had been applied.

In general outline it follows the curves of the preceding experiments. The stone probably offered less resistance to the passage of water, which may account for the slightly higher average pressure throughout its length. Further readings were taken, but besides showing the effect of clogging of the pores nothing new is shown, and they are therefore not inserted.

CEMENTS.

I. Neat Portland.

The size and character of the pipe is shown in Plate VI, Fig. 1. The cement used was Empire Portland. The amount of water used in the mixture was .205# to 1# cement. The cement was thoroughly mixed and tightly rammed into the 4-inch iron pipe.

The smaller tubes (3/8 inch) were inserted before cement was put in and tightly held in place by frames, made for the purpose as before described, until the cement became firmly set. The pipe, filled with cement, was allowed to stand for 72 hours before subjected to water pressure. Pressure was applied February 22, at 5 P. M. It was soon noticed that the water did not succeed in forcing its way through the cement, and in order to aid it in thoroughly saturating the cement, artificial pressures were applied through each of the small piezometer tubes. The mercury in the gauges which were conected to these tubes was so

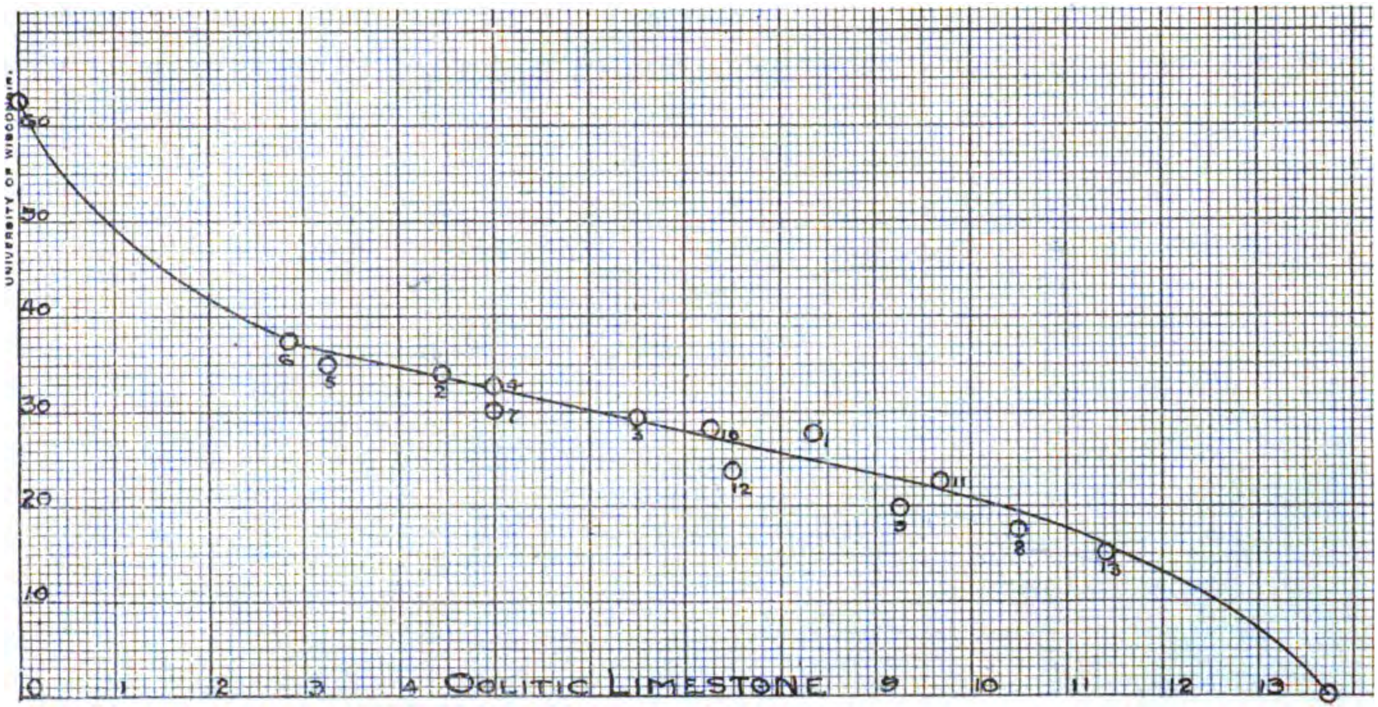

UNIVERSITY OF WISCONSIN.
OOLITIC LIMESTONE
0
1
2
3
4
9
10
11
12
13
10
20
30
40
50
60

FIG. 170.

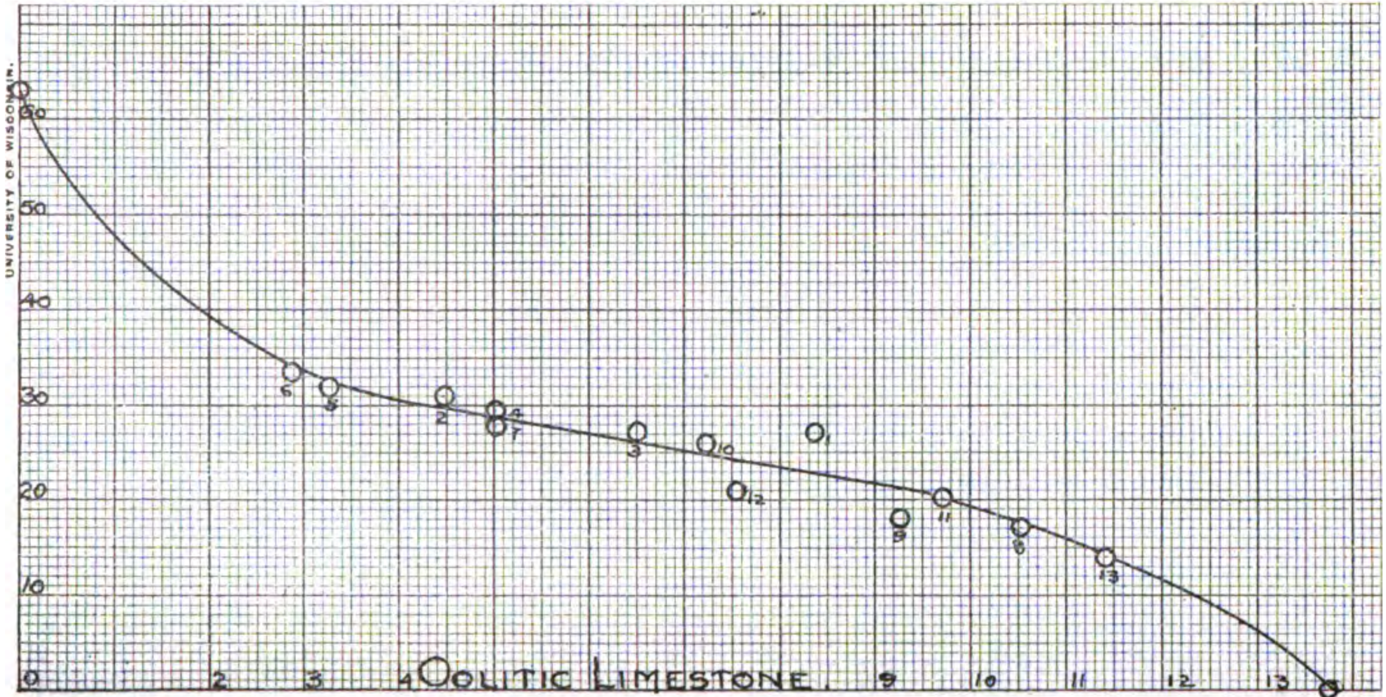
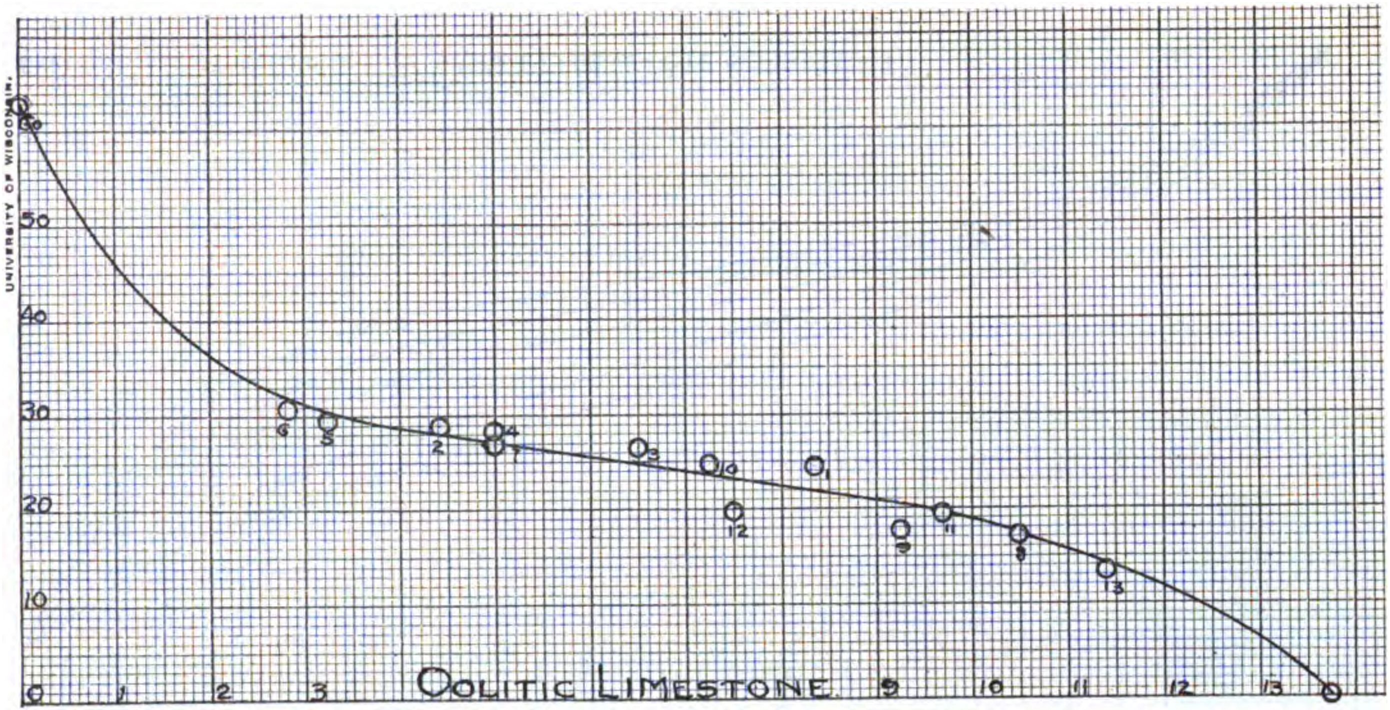

OOLITIC LIMESTONE.
UNIVERSITY OF WISCONSIN.
60
50
40
30
20
10
0
2
3
4
9
10
11
12
13

FIG. 171.



UNIVERSITY OF WISCONSIN.
OOLITIC LIMESTONE
60
50
40
30
20
10
0
1
2
3
9
10
11
12
13

FIG. 172.

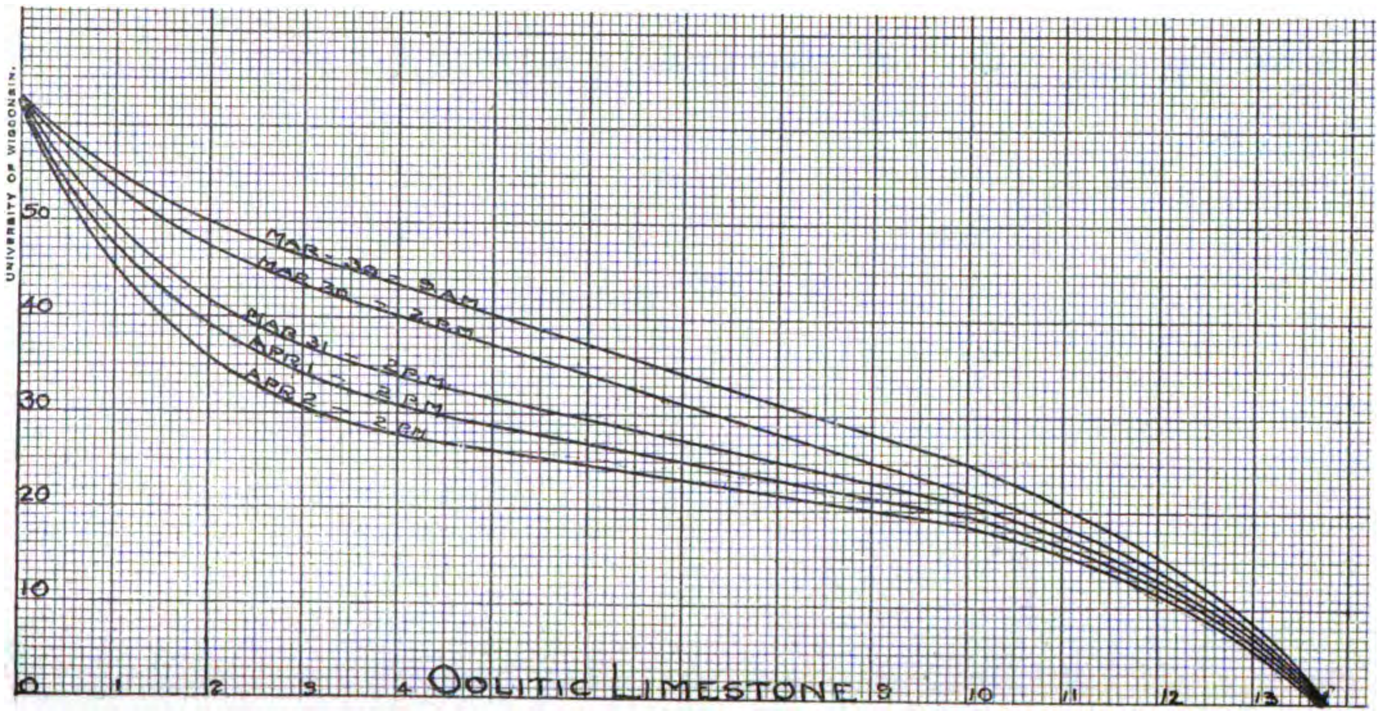
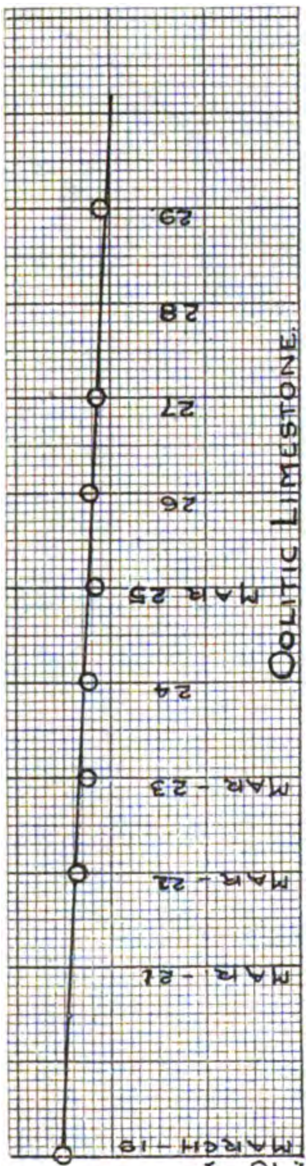
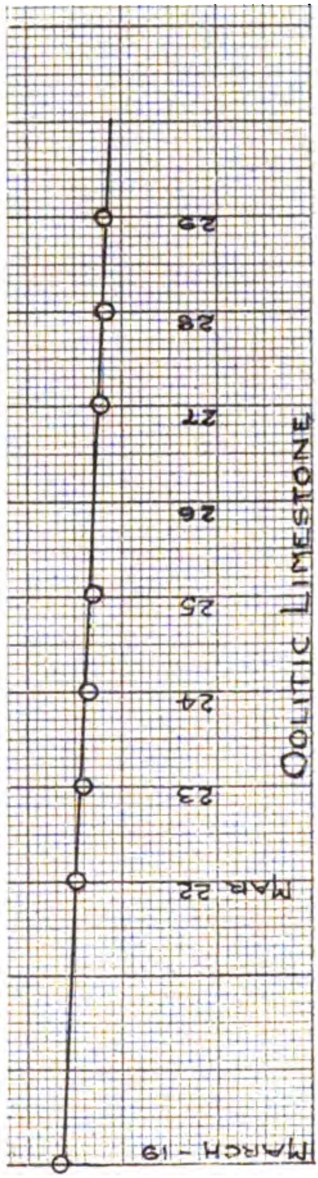

UNIVERSITY OF WISCONSIN.
MAR-30 - 9 AM.
MAR 30 - 2 P.M.
MAR 31 - 2 P.M.
APR 1 - 2 P.M.
APR 2 - 2 P.M.
OOLITIC LIMESTONE
0
1
2
3
4
9
10
11
12
13
10
20
30
40
50

FIG. 173.



Hole No. 5. Fig. 174.



Hole No. 6. Fig. 175.

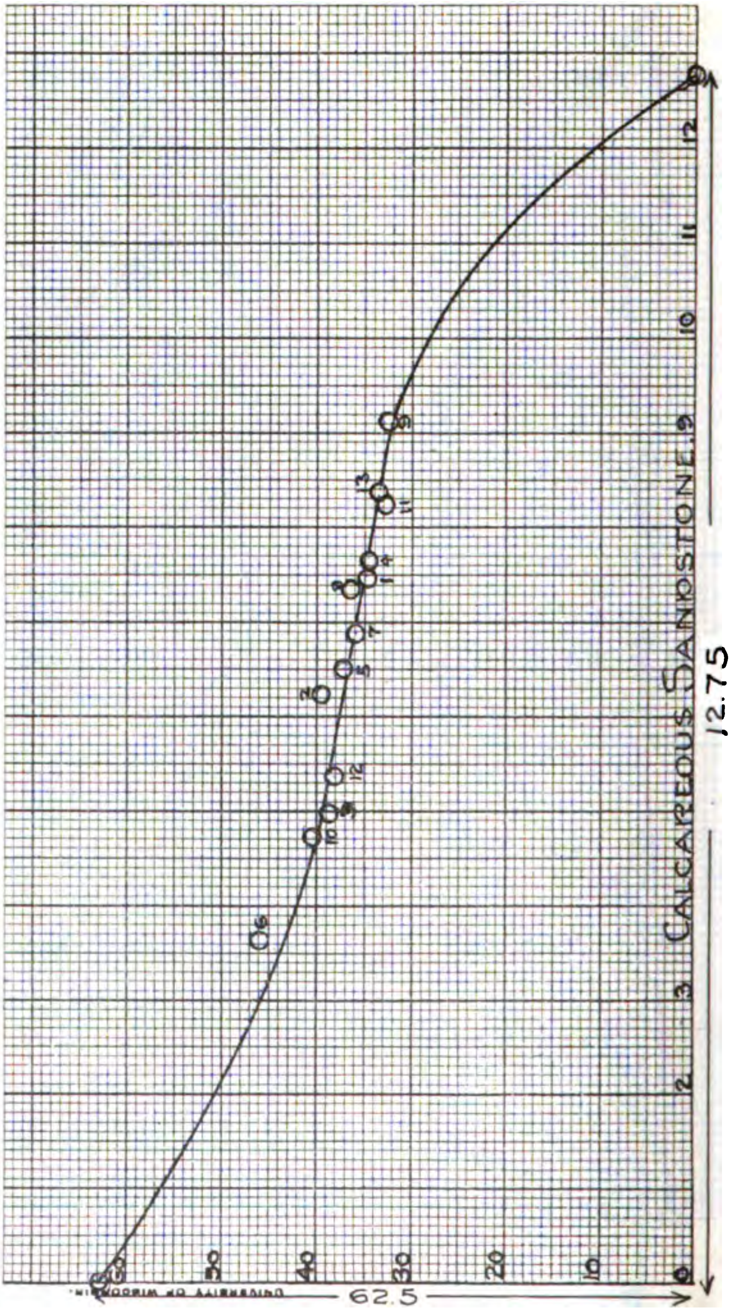


Fig. 176.

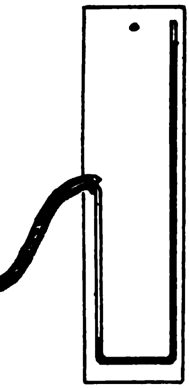


FIG. 177.

placed that it exerted a considerable pressure on the water in the shorter arm, and consequently on the cement in the pipe. The mercury naturally dropped back to a level in the course of time, and then the pressure was again renewed. This was continued until April 10, a period of almost seven weeks, without any result. The mercury in the gauges during this time continued to fall, but whether this was due to a possible leakage out of the rubber tube connecting the gauge with the iron tube, or to the absorption of the water in the tube by the cement it is impossible to say with certainty. The cement was removed from the pipe with great difficulty and it was found that the interior of the cement was perfectly dry, the only t spots occurring around the bottoms of the piezometer tubes on and near the face upon which the pressure was exerted.

may here be interesting to note that briquettes of neat land cement used to determine the tensile strength of the ;, after being placed in water for a period of seven days, show, being broken, only a slight penetration of the water into the ent itself, not more than ⅛ inch as an average. A 4-inch of neat Portland placed under water for a period of three ths showed an average penetration of about ¼ inch, this unt being exceeded only where numerous small air pockets rred.

nsidering the time allowed for the passage of the water ugh the cement, and the pressure from the additional supply ne small tubes, it would seem to be true that neat Portland ent is practically impervious to water. Some further exnents with thin layers practically substantiate this statement, ill be shown later.

Portland Cement Mortar, one part sand to one part cement.

or a figure and a description of the apparatus used, see Plate Fig. 2, and the preceding pages.

ne cement used was the same as in the preceding experiment, ely, Empire Portland. The sand used was crushed quartz. of sand:

2,500 parts, none caught on number 20 sieve.
2,223 parts, caught on number 30 sieve.
257 parts passed through number 30 sieve.

2,500, total.

ne proportion of mixture was 1# cement, 1# sand, .27# water. fter allowing the cement mixture to set 72 hours, it was put er pressure and continued from April 26 until May 6 without

any signs of transmission of water pressure. The pressure was released with the intention of allowing the mixture to rest for some time with the object in view of allowing the material caught on the surface to oxidize. The mixture was allowed to stand open in the air 12 days, when it was again subjected to pressure for 8 days, but no signs of transmission of pressure were visible. Whether a longer period would show these same results it is difficult to state. The results obtained, however, show that this ratio of mixture is impervious to water in a marked degree.

III. Portland Cement Mortar, 2 parts sand to 1 part cement.

For description and details of apparatus see Plate VI, Fig. 2, and some of the preceding pages.

The sand and cement were the same as that used in the preceding experiments. The pressure was applied to this mixture on April 19. Through an unfortunate accident, tubes numbered 1 and 2, the two nearest the pressure face, became loose and the pressures recorded by them were therefore affected to a large extent. These pressures were exceedingly high and show that the accident probably produced some internal fracture in the cement. They were neglected in plotting the curves, but to show the variation in these two gauges they will here be given:

	2 P. M., Apr. 20.	2 P. M., Apr. 21.	2 P. M. Apr. 22.
No. 1	62.5	62.5	62.5
No. 2	49.0	42.8	38.8

The results of the experiment are best seen on three curves plotted, 178-179-180. The pressures, at the various points, follow a straight line quite closely. That the loose tubes, Nos. 1 and 2, and the possible existing fracture materially influenced the pressures in the following tubes is without doubt. To what extent, however, they were influenced it is difficult to say. The writers have plotted the curves as though no disarrangement existed. It was thought at first that it might be advisable to regard hole No. 1 as the face of the stone and plot the rest of the points in accordance with it, but after considering the uncertainty of the internal conditions the plan adopted was deemed more advisable. If hole No. 1 was fed through some small crevice the increased resistance to a constant flow throughout the stone caused by the water being drawn only through the small supply crevice, which would act as a kind of distributing well, would tend to reduce the actual pressures in the remaining tubes.

The clogging of the surface is also very distinctly shown in this case. This effect is shown in an almost abnormal state in some of the holes, as in No. 2 for instance (above noted). Whether this is produced entirely by the filtering action is doubtful, and it does seem as if some different action existed in the cement than in the stone. The cement had been allowed to set in the air and was perfectly dry when the water pressure was ap-

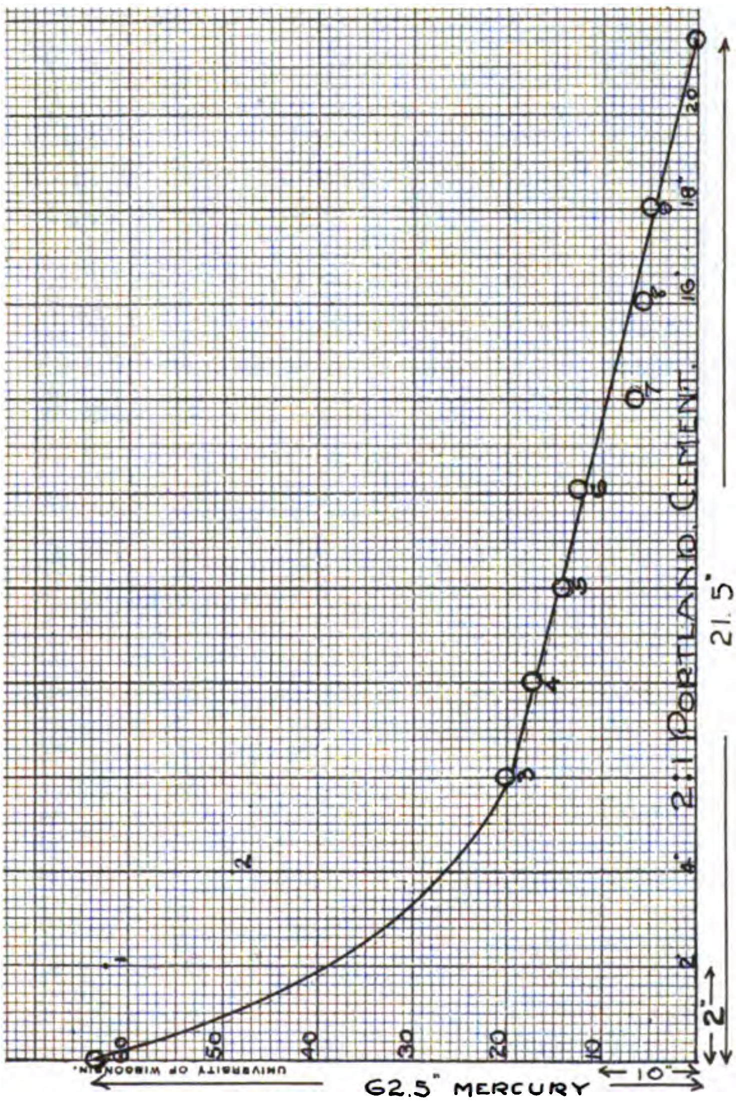

2:1 PORTLAND CEMENT.
21.5"
62.5" MERCURY
10"
2"
UNIVERSITY OF WISCONSIN.

FIG. 178.

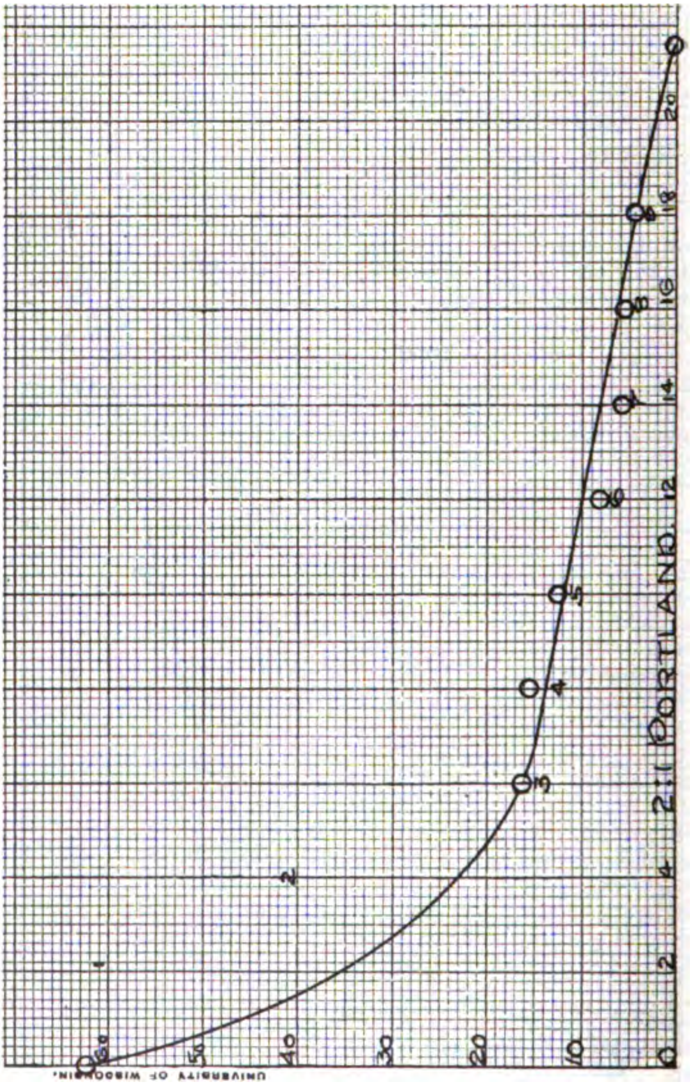


FIG. 179.

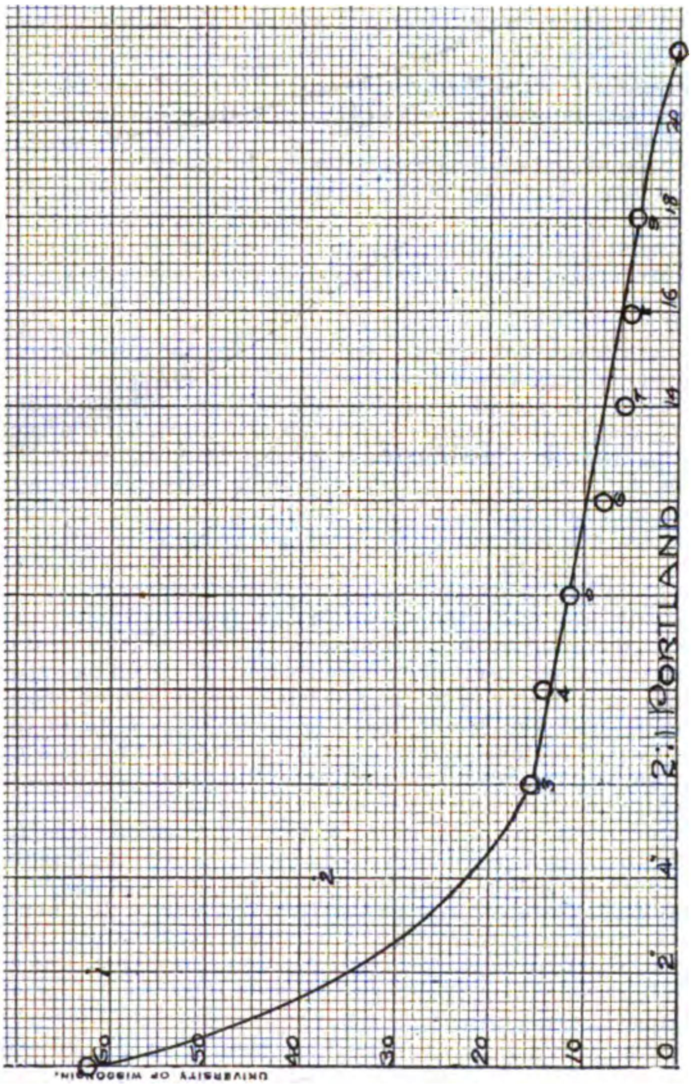


Fig. 180.

plied. It is possible that the entrance of the water into the rock produced some effect upon the cement, either by combining with it and forming some other compound within, or by expanding it. This will be shown more clearly in some of the following experiments.

IV. Portland Cement Mortar, 3 parts sand to 1 part cement.

The details and dimensions of the apparatus are shown in Plate VI, Fig. 2.

The cement and sand were the same as in the preceding cement experiments. The ratio of the mixture was:

Sand....................................	3
Cement..................................	1
Water...................................	.33
	4.33

When pressure was applied to this mixture, the water seemed to flow through quite readily, appearing on the lower face in a very short time. It issued from the whole face with considerable freedom and to a far greater extent than in any of the preceding cases mentioned. The water in flowing from the entire face of the cement shows quite conclusively that it flowed through the cement mixture itself and not along any crevice between the cement and the iron pipe. No leakage around the edge of the pipe coming from this possible defect could be discovered which was at all in excess of the leakage over the entire face.

The pressure was applied on March 27 at 2:30 P. M., and the readings recorded by curve No. 181 were taken March 29 at 9 A.M. The pressures increased quite rapidly and, as could be expected, unevenly at first, due to the fact as has been mentioned of a larger source to draw the water from in some cases than in others.

Time was therefore allowed for the pressures to reach a settled condition, and the readings represented by the curve were taken after this condition had appeared.

In order to secure another set of these maximum pressures before the filtering action had had any effect, the water pressure was shut off immediately after the above reading was taken. The cement was allowed to rest until 9 P. M. on March 30, when pressure was again applied. The pressures now were considerably slower to rise than in the preceding case, and on April 1 at 2 P. M. the readings were as represented by curve Fig. 182. A longer time had elapsed between the application of pressure and the first reading of the gauges, as represented by Fig. 181, than in the first instance, and yet the pressures recorded were far lower than in that case, as will easily be seen by a comparison of the two curves. The possible cause of this has already been mentioned, namely, that the water which entered the stone formed some compound within, which tended to make the material denser and hence more impervious to water. That this effect shown by this last comparison was not caused by the filtration of the water is evident,

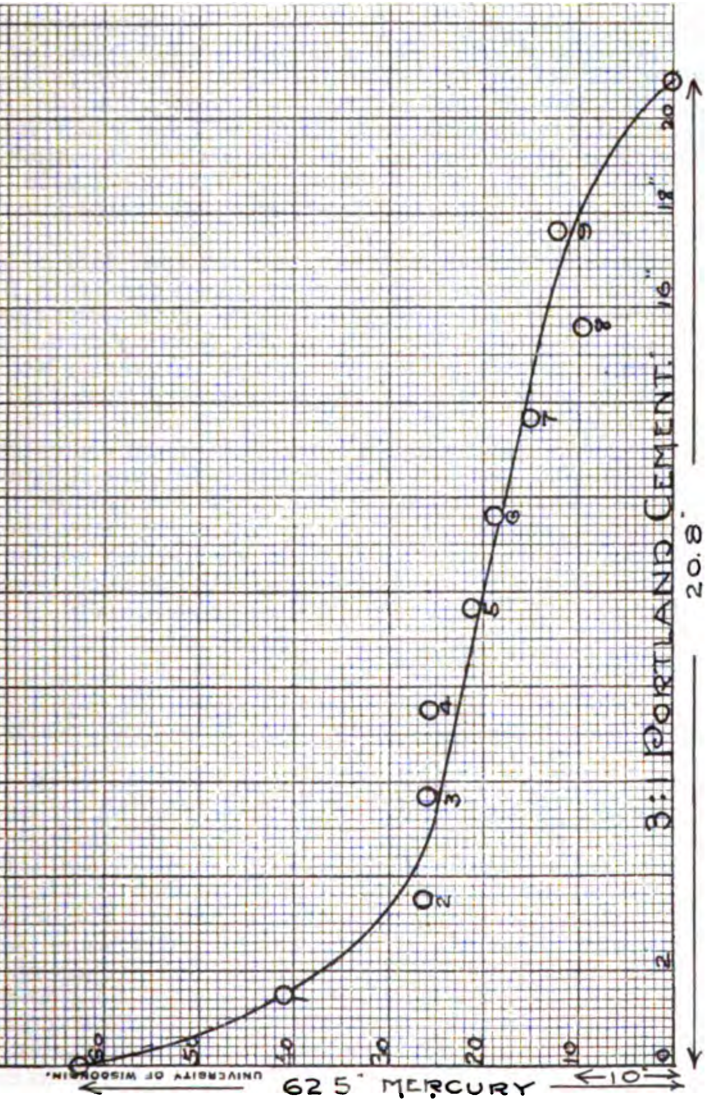

3:1 Portland Cement.
20.8"
62 5" Mercury
10"
University of Wisconsin

Fig. 181.

and that it was caused by some internal action is also evident. The water pressure was continued for a period of nearly two weeks, and during this time a continual rise of the pressures in the gauges was noticeable. This is shown in the following set of curves, Figs. 182-183-184-185-186-187-188. Twenty represents the highest pressures obtained during this period, and with the exception of Fig. 181 represents the maximum. The different points on Fig. 188 follow the general curve more closely than do those of Fig. 181, due to the additional length of time which it had in which all of the pressures could become settled. A comparison between Figs. 188 and 181 will show a general similarity in outline of the curve, with, however, lower recorded readings on Fig. 181 than on Fig. 181.

A comparison between Figs. 181 and 168 (on Oolitic limestone) will show a general agreement in type of curve with, however, a more rapid fall of pressure near the face of the cement than in the limestone. The item of note, however, is the general agreement in the outline of the curves. Curves on No. 189 show probably more clearly the rate of the rise of pressures than the separate curves.

Other mixtures than those mentioned of Portland cement were not tried. The four used show that for ordinary mixtures, namely, 2:1 and 3:1, the water pressure is transmitted quite readily. The other two mixtures, neat and 1:1, did not, as has been shown, transmit the pressure with the head of water which was at our disposal for producing the pressure, yet with a greater pressure these mixtures may, to some extent, show similar results.

ROSENDALE CEMENTS.

V. Neat Rosendale.

For size and description of apparatus see Plate VI, Fig. 1. The brand of cement used was Milwaukee Rosendale. Ratio of mixture, 1# cement, .44# water.

It was rammed into the pipe tightly and allowed to set nine days. Pressure was applied April 19 and continued for six weeks. The same method of aiding the flow of the water through the stone, as in the neat Portland cement experiment, by application of artificial pressures, was resorted to. The effect produced in the neat Portland was also found in the Rosendale. The artificial pressures were frequently renewed, showing that some water entered the cement, and yet at the time noted above no internal pressure was found. The mercury in the gauges continued to fall, and probably if the experiment were continued for a sufficient length of time, until the cement had become thoroughly saturated, a different condition of things might have been found to exist. That the cement is practically impervious to water is, however, conclusively shown. In removing the cement from the pipe it was found that moist spots existed around the bottom of the piezometer tubes, showing that some water had entered the cement through these tubes.

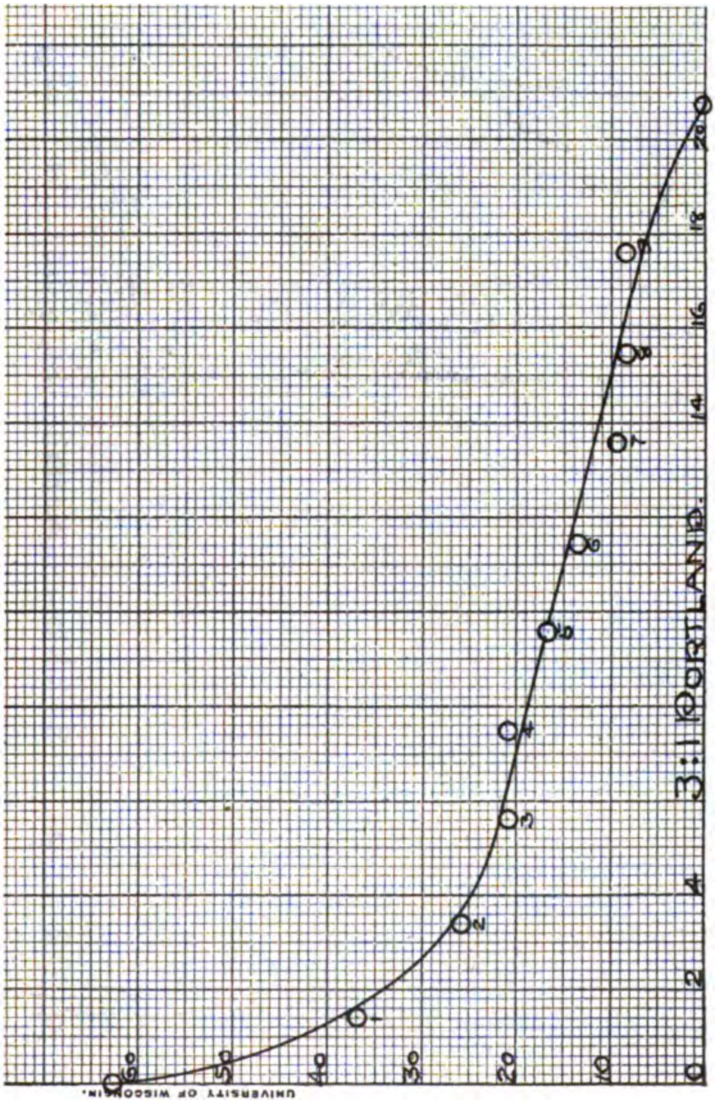


FIG. 182.

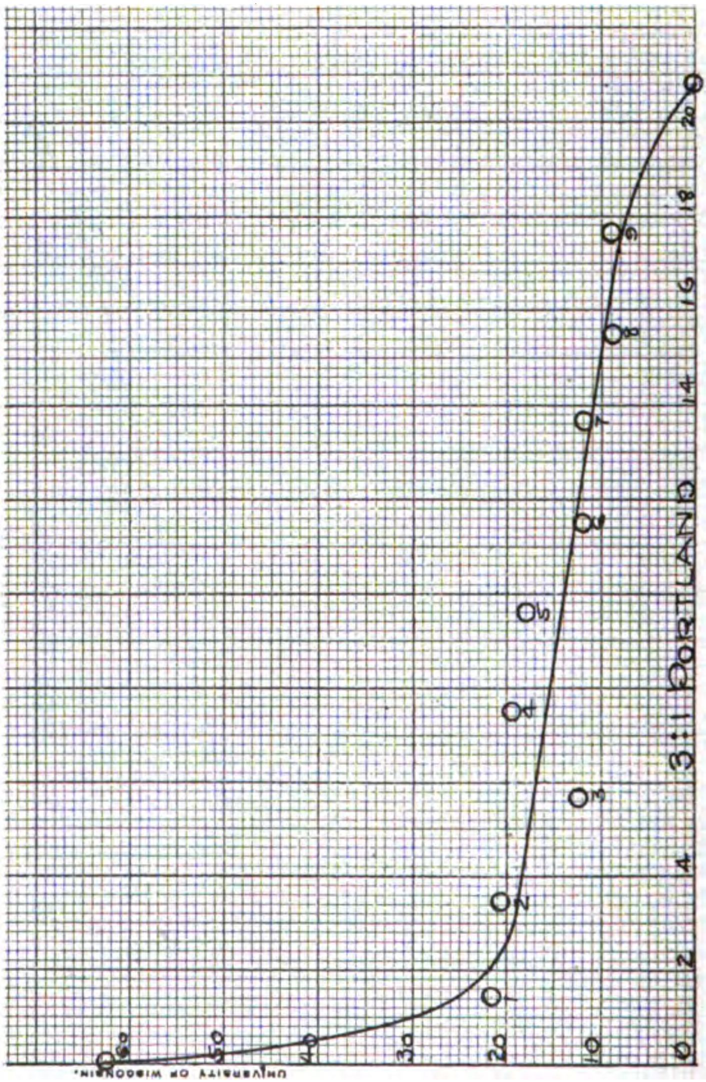


FIG. 183.

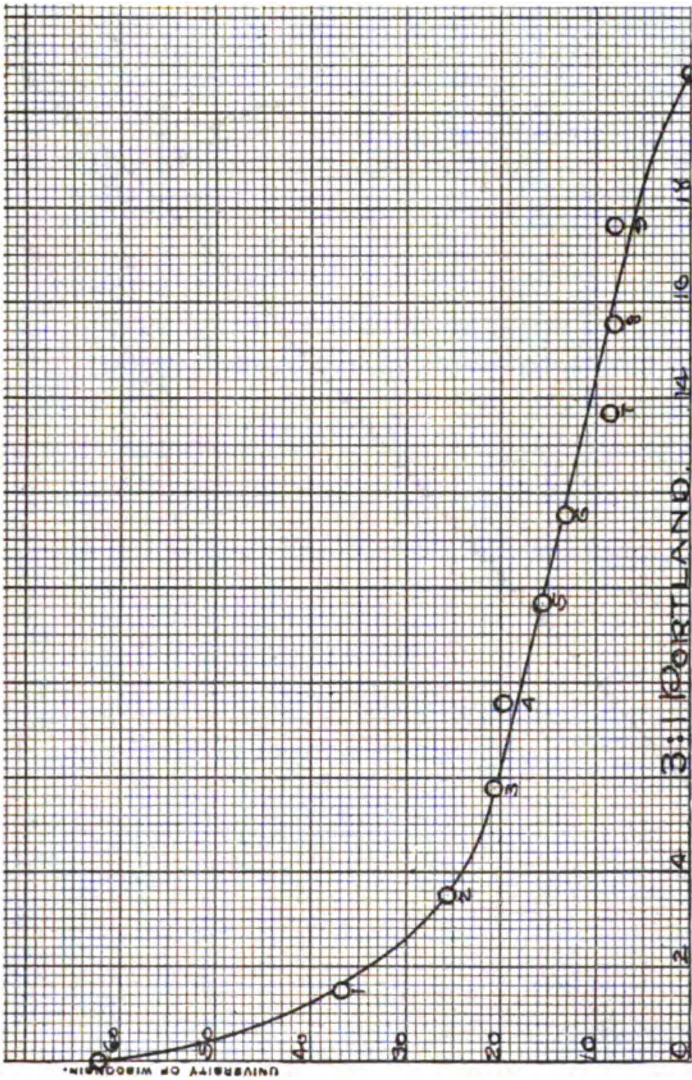

3:1 PORTLAND.
0
2
4
14
16
18
10
20
30
40
50
60
UNIVERSITY OF WISCONSIN.

FIG. 184.

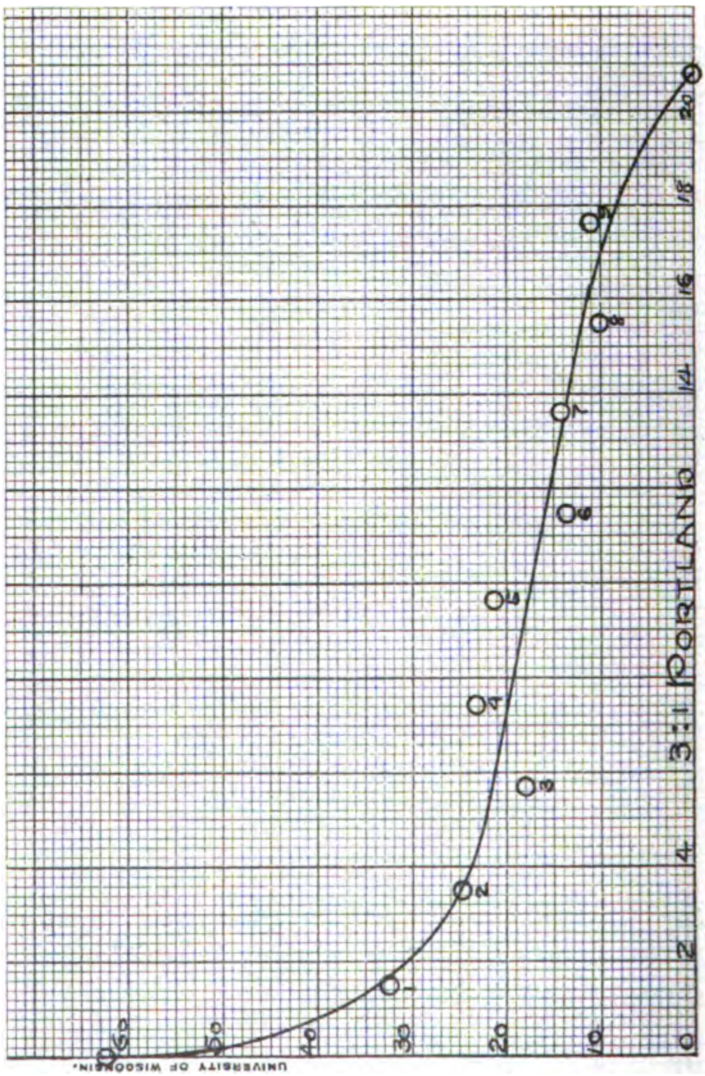

3:1 PORTLAND
UNIVERSITY OF WISCONSIN.
0
2
4
12
14
16
18
20
10
20
30
40
50
60

FIG. 185.

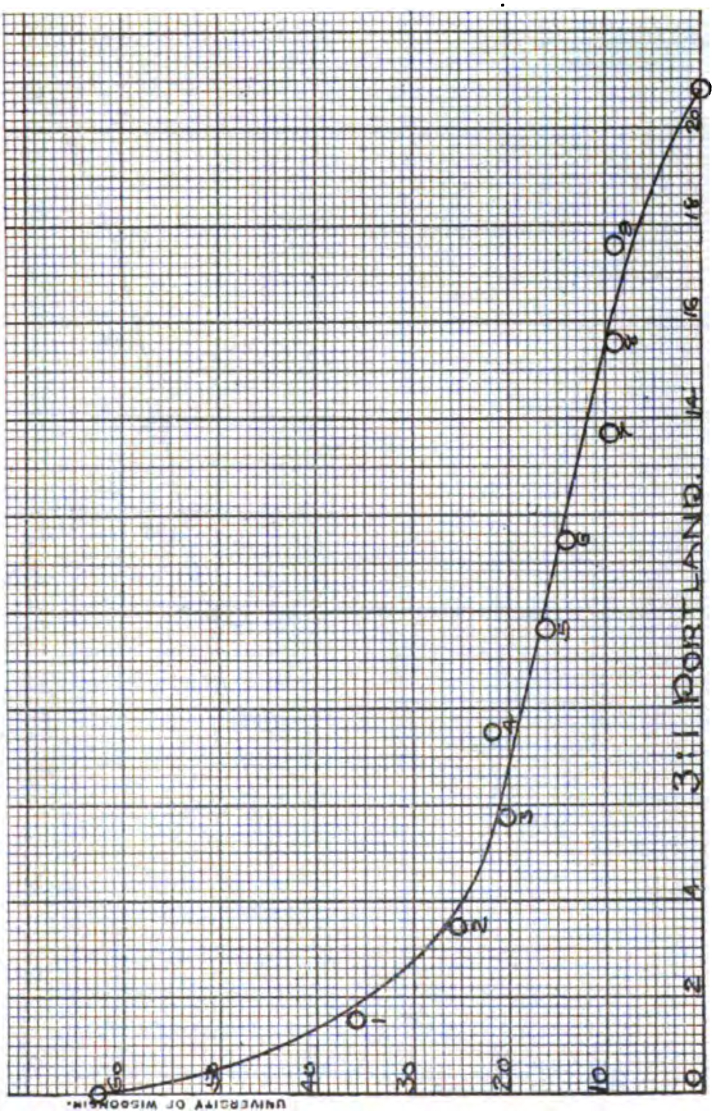


FIG. 186.

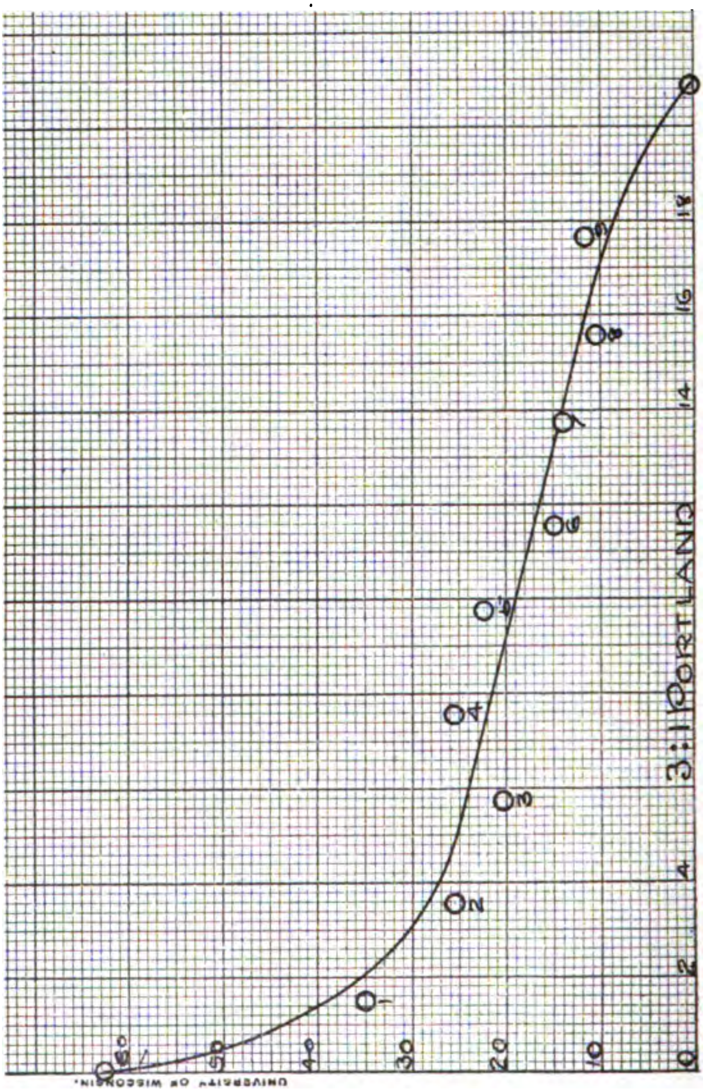


Fig. 187.

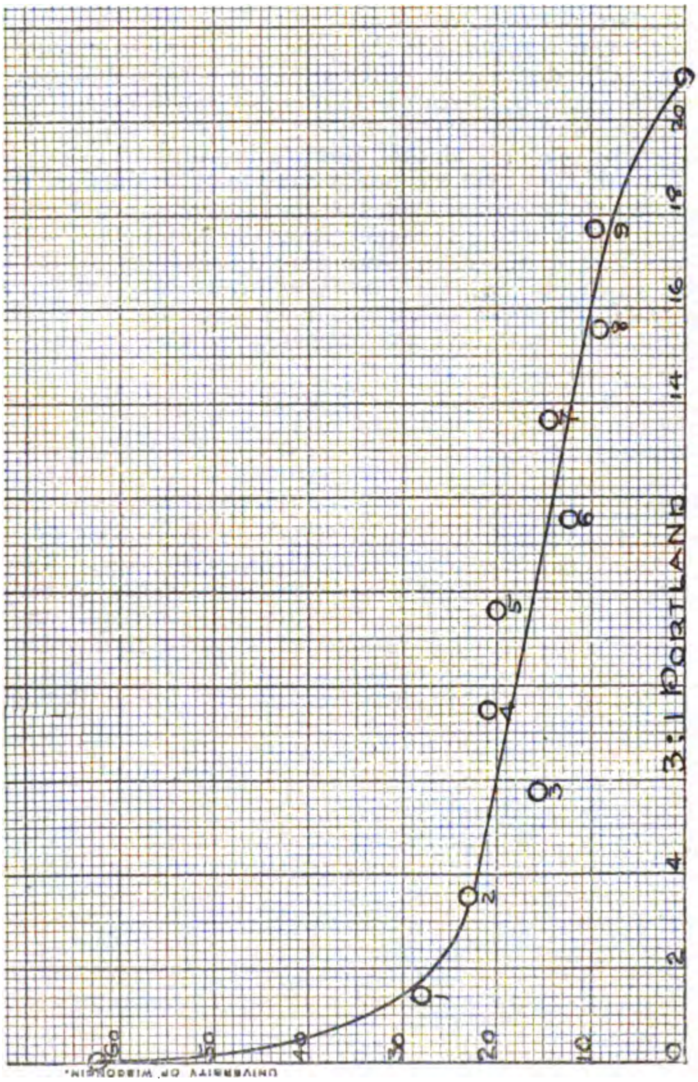


Fig. 188.

VI. Rosendale Cement, Mixture, 2 parts sand, 1 part cement.

For a diagram and description of apparatus see Plate VI, Fig. 3, and those preceding pages devoted to this purpose. The pipe was five feet long and the piezometer tubes were placed eight inches apart.

The cement was put into the pipe in the same manner as in those already described. After allowing a sufficient length of time for the cement mixture to thoroughly set, it was subjected to pressure on May 6, at 2:45 P. M.

The set of readings on this pipe are incomplete, owing to the fact that sufficient time was not at hand to await the final results. The complete curves cannot, therefore, be shown, but sufficient readings were had to give some idea of the variation of pressures, and these are given. The following are the readings on the various gauges which showed any signs of pressure on May 7 at 10:15 A. M. These were, therefore, taken 19½ hours after the water pressure was applied. The gauges are numbered respective to their order from the pressure face.

	May 7	May 13	May 18
No. 1	57.0	43.1	37.5
No. 2	13.5	30.2	29.0
No. 3	1.5	22.5	27.3
No. 4		4.1	6.4

From these it will be noticed that the passage of the water through the cement mixture was comparatively slow. Also that the filtering effects of the water become noticeable in the early stages of the experiment, in that the pressures near the face subjected to pressure are falling, while those farther removed from it are rising. It seems at the present writing that it is only a question of time when the water will have passed through the entire length of the cement.

CEMENT COATINGS ON STONE.

In order to study the effects of a coating of cement on the stone, experiments to that end were performed.

The Oolitic limestone was used for the purpose and the coating was put on the side exposed to the water pressure in as even a manner as possible. On account of the unevenness of the surface of the stone, an accurate determination of the thickness of the various coatings could not be made. Several measurements of the hardened cement were made after the experiment was completed.

The face of the stone was thoroughly cleaned by the method before alluded to, so as to remove as much of the infiltrated matter as possible. All of it, however, could not be removed, and in a comparison of the following curves with those of the plain stone itself this fact must be taken into consideration. The amount of allowance to be made is, of course, a difficult thing to

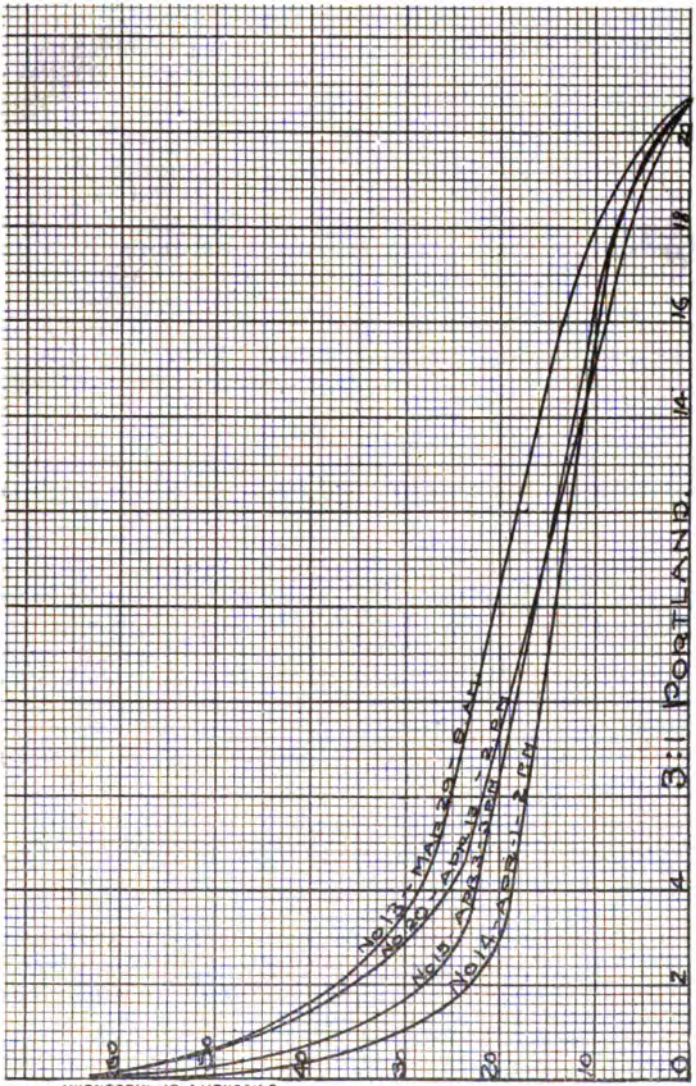

3:1 PORTLAND.
No13 - MAR 29 - 8 AM
No20 - APR 13 - 3 PM
No15 - APR 3 - 3 PM
No14 - APR 1 - 3 PM
0
2
4
14
16
18
20
10
20
30
40
50
60

FIG. 189.

decide upon. If the last readings on the plain stone, directly after a cleaning had been made, be taken as a guide, the curve which would result would lie about midway between Fig. 169 and Fig. 170. Later readings than those shown in the curves for Oolitic limestone were taken and a record kept of the same, although it was not thought necessary to insert them, the number inserted being deemed sufficient, and it is upon these readings that the estimated pressures are based.

I. Oolitic limestone with a coating of 1:1 Rosendale cement.

The cement, as has been stated, was put upon the stone in as even a manner as possible, the average thickness varying between about 3-16 and ¼ inch. The cement mixture was made of the same brand of cement as before referred to, and of the same quality of sand. After applying it to the stone it was allowed to set 48 hours. The readings recorded by curve Fig. 190 were taken 50 hours after pressure had been applied. Not much need be said about the results A comparison of this with the other curves of the Oolitic limestone shows, as might have been expected, a diminution of pressures.

Fig. 191, plotted from pressures taken 48 hours after 190 was taken, shows a decided fall in pressures which is probably due to both the filtration of the water and also to some extent, as has already been explained, to the compound apparently formed within the cement itself. The curves as plotted probably do not represent the actual condition between the face of the stone and the first hole. The pressure is of course lost in the thin coating of cement owing to the increased resistance, and hence the straight lines have been drawn, making a curve of broken lines.

That a coating of cement of this mixture is not very effective in diminishing the existing pressures is quite apparent, and its use for this purpose would hence not be advisable.

In order to ascertain the effect of denser mixtures, neat Portland and neat Rosendale were tried.

II. Neat Portland coating on limestone.

The thickness of this coating was approximately the same as the preceding. The cement was allowed to set 24 hours and the first readings, represented by curve Fig. 192, were taken 24 hours after the pressure was first applied. The curves show very plainly the effect of this coating, and a comparison of curves Figs. 192 and 193 with the original curves on the limestone will show a very considerable diminution of pressure.

Curve No. 194, taken 48 hours after No. 192 was taken, shows a further diminution of pressure the same as has been mentioned before in the case of 1:1 Rosendale cement, and for the same reasons. From these two curves, together with the experiments made on the neat Portland cement itself, it must be inferred that this cement mixture is nearly water tight, and that it can in ordinary cases be assumed as such. A study of the effect of a

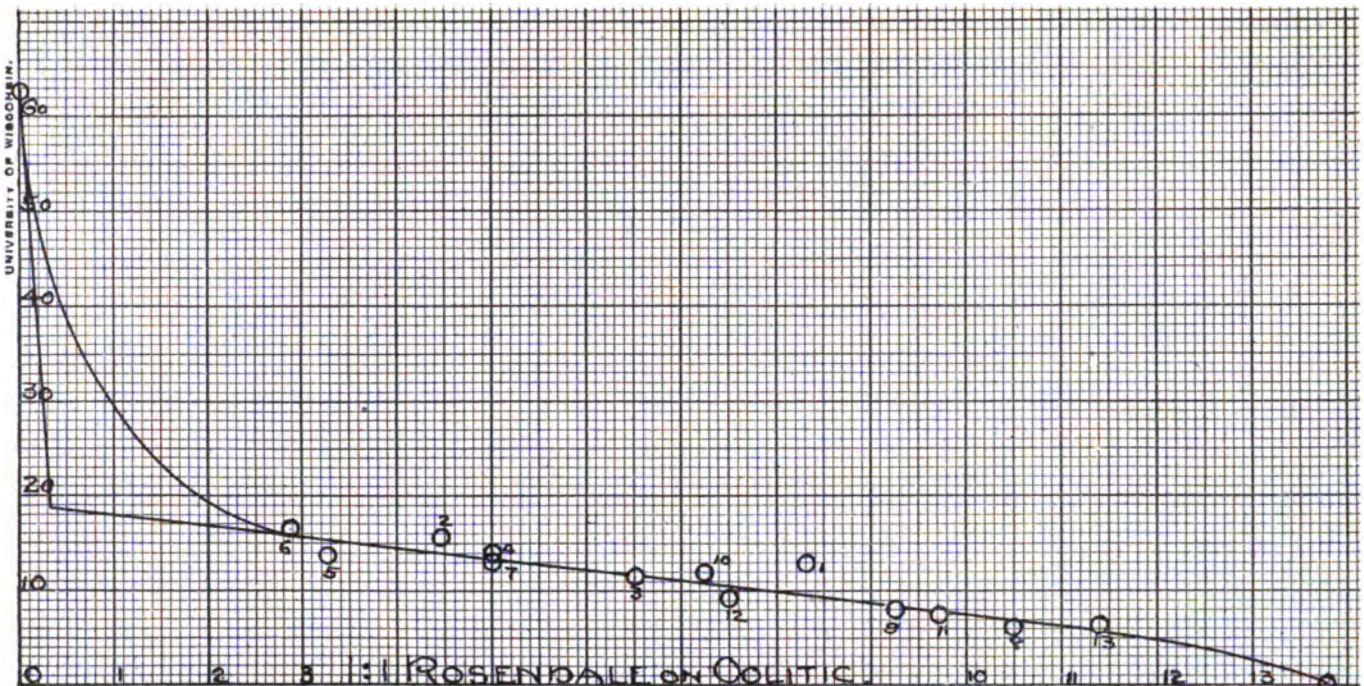
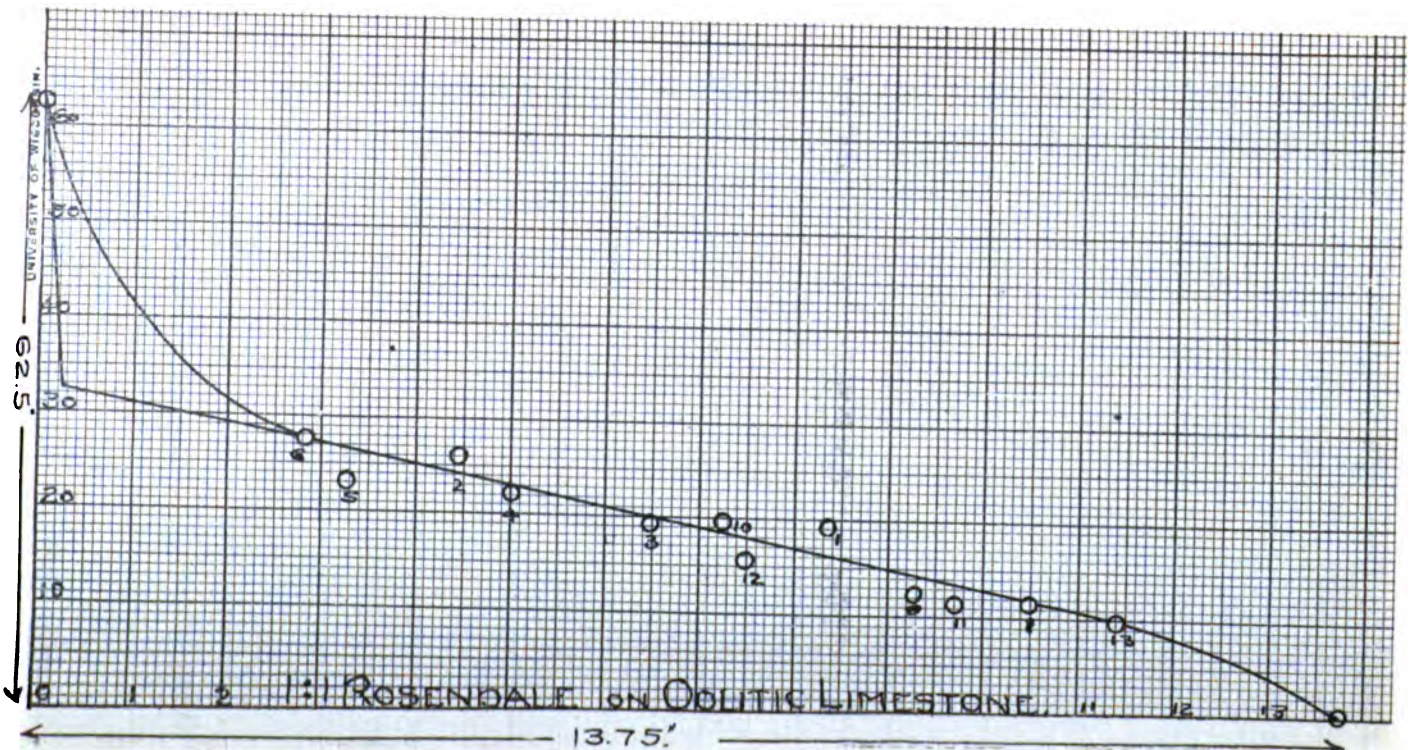


FIG. 190.


1:1 Rosendale on Oolitic Limestone.
62.5
13.75'
University of Wisconsin.
0
1
2
11
12
13
10
20
30
40
50
60

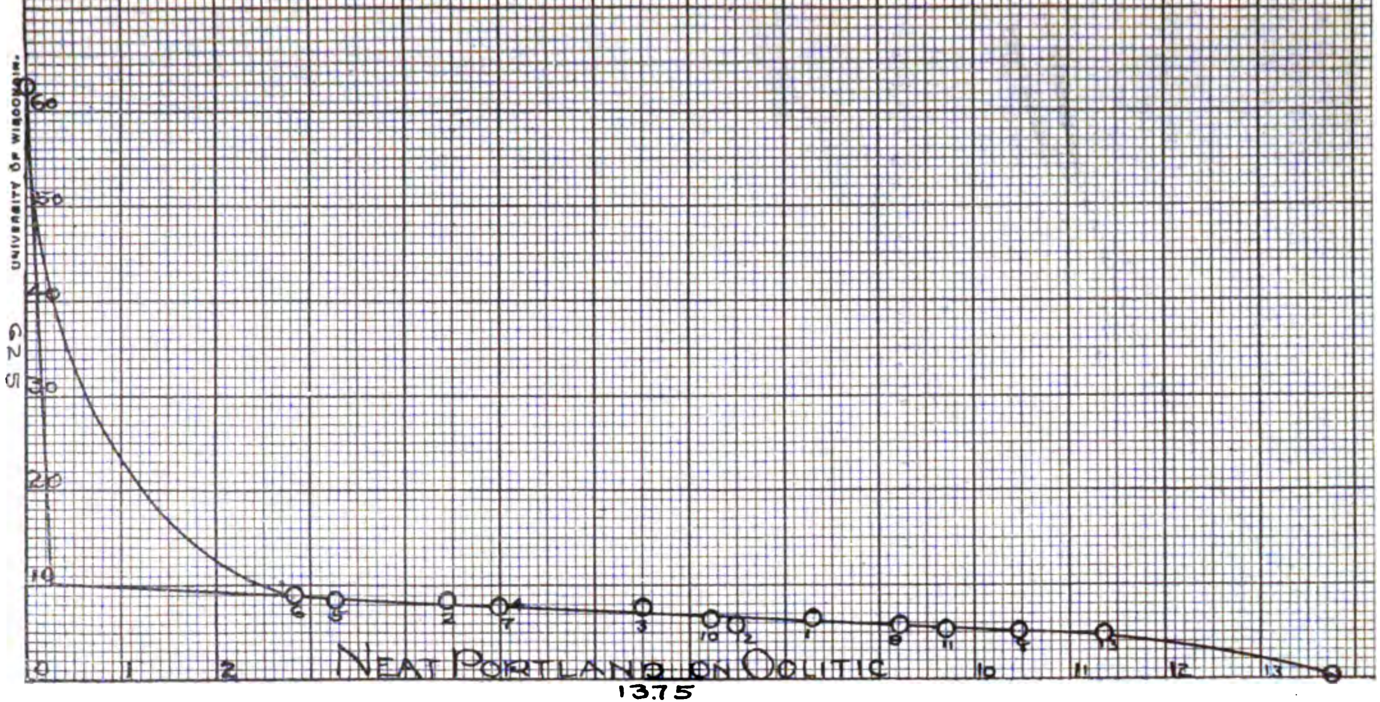


FIG. 192.

higher head or a greater water pressure on the cement itself might, however, show that the pressures may be transmitted more readily. The coating used was comparatively thin, but it was quite effective in reducing the pressures.

III. Neat Rosendale.

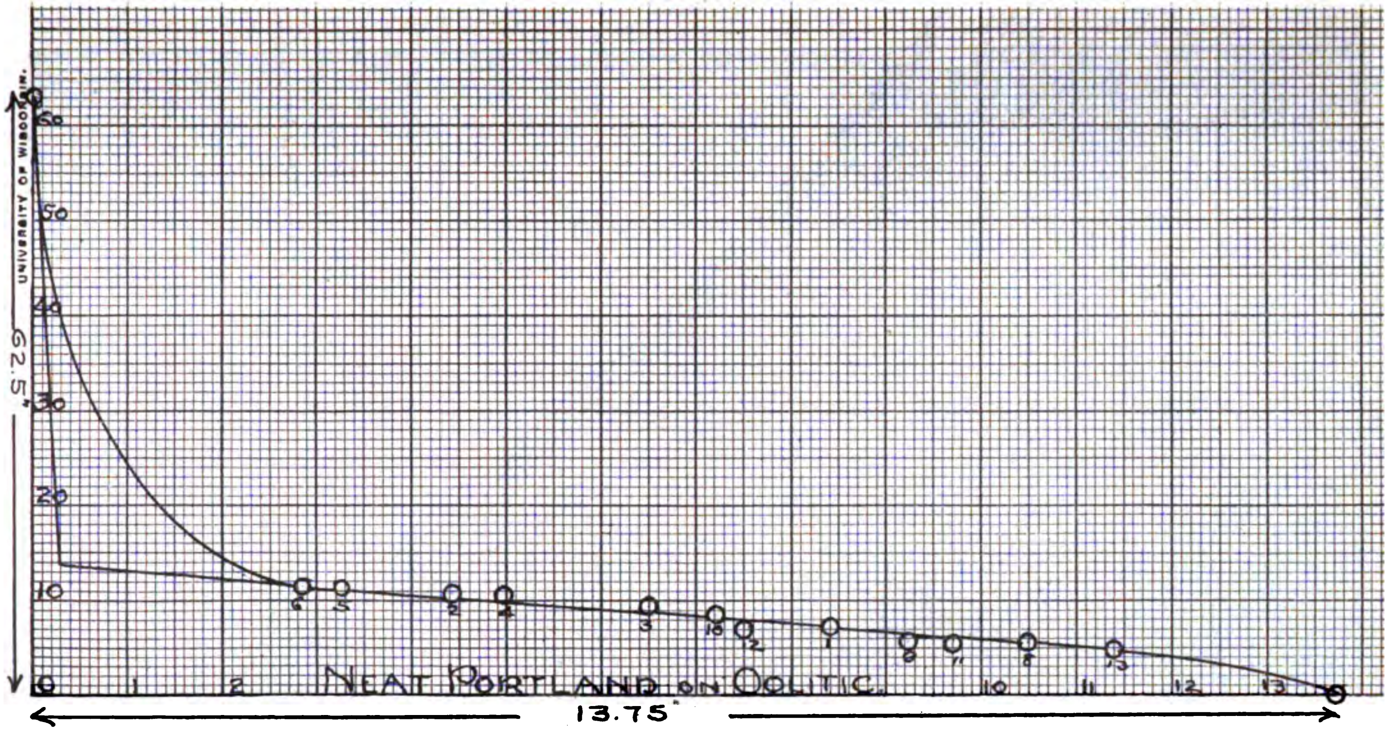
Curve Fig. 194 shows the effect of a coating of neat Rosendale From this curve it will be seen that this coating, though not so effective as neat Portland, also aids in diminishing the pressures.

The coating was applied to the stone in the same manner as the preceding, and had approximately the same thickness. It was allowed to set 68 hours before the pressure was applied, and the accompanying curve was taken 48 hours after that time. The pressures recorded follow approximately a straight line. The resistance to the passage of the water being considerably increased causes a more rapid fall of pressures near the face of the stone exposed to the water pressure, thus accounting for the broken line as representing the variation of pressures

DEDUCTIONS FROM THE CURVES.

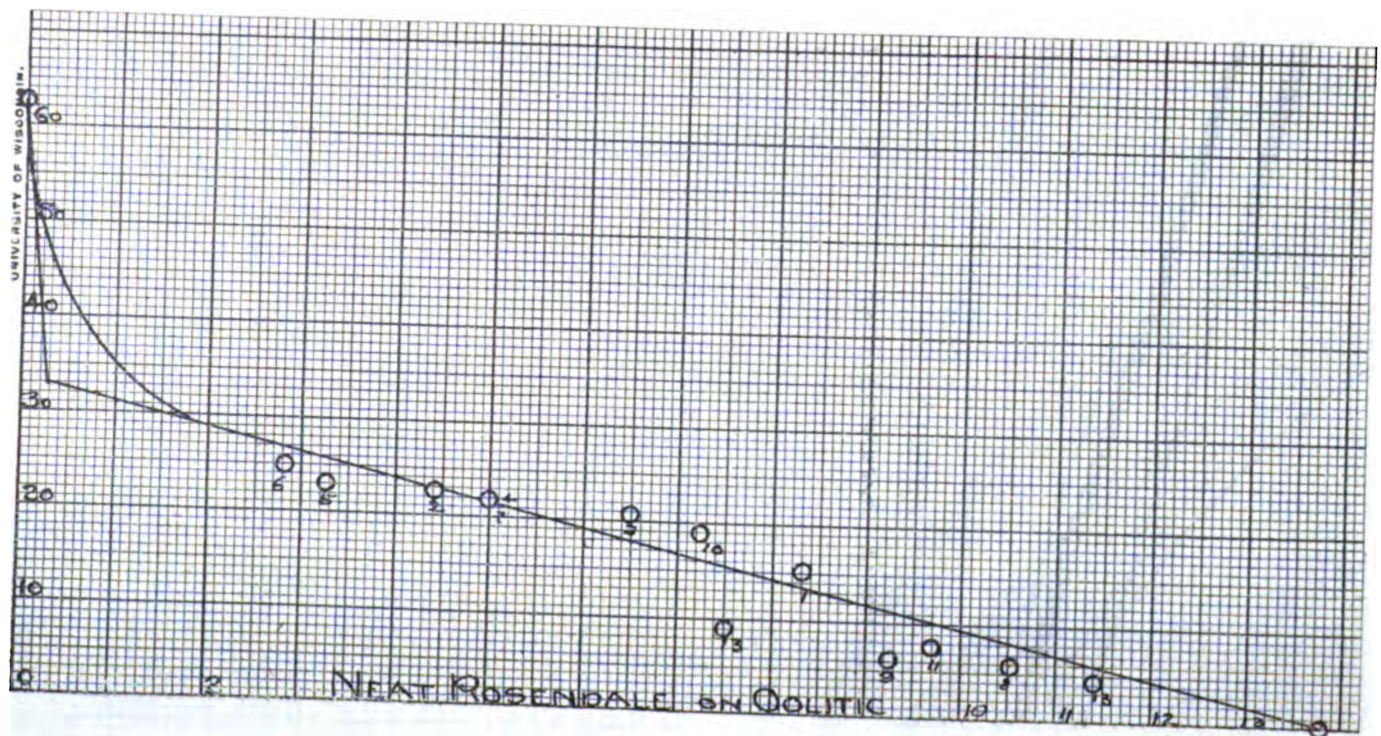
Taking the curves into consideration as a whole, several points of interest may be noticed. First, that the water does not flow through the stone merely in a "capillary manner," as assumed by Mr. Wegman in the discussion referred to at the beginning of this paper, but under pressure varying as shown by the curves. Second, that a striking similarity exists in the shapes or forms of the curves of different materials and used under different conditions with different apparatus. We believe that this similarity shows that the precautions taken to obtain a flow of the water through the stone in the designated paths were very satisfactory, and that no uncertain element enters into the final results. We were no doubt handicapped to some extent by the impurities in the water which clogged the pores, but this element of uncertainty was known and treated accordingly. The maximum readings given in this paper were generally had before filtration had had much chance of action. Where the denser materials were experimented upon, the time of passage of the water through the rock was necessarily greater, and a correspondingly increased clogging effect could be noticed.

From the different shapes of a series of curves, say the series on the Oolitic limestone, best shown in Fig. 173 of the curves, it will be noticed that a more rapid decrease of pressures exists near the face of the stone (the face upon which the pressure was applied), than towards the end of the stone open to the air. This was, no doubt, due to the action of the infiltrated material. This material was caught in the fore part of the stone, most of it being caught on the face, and thus would naturally influence the nearer gauges more than the distant ones. This was shown in some cases by the fact that some of the forward gauges were falling while the rear ones were still rising, the effect due to the clogging



UNIVERSITY OF WISCONSIN.
62.5"
60
50
40
30
20
10
0
1
2
10
11
12
13
NEAT PORTLAND ON OOLITIC.
13.75"

FIG. 193.



UNIVERSITY OF WISCONSIN.
60
50
40
30
20
10
0
2
10
11
12
13
NEAT ROSENDALE ON OOLITIC

FIG. 194.

of the pores not having reached them at the time. This, no doubt, is the reason why the curve takes the form it does take, namely, that of a reversed curve. Take Fig. 168 on Oolitic limestone for instance; on this the reverse of the curve is very slight, the curve approximating a straight line, but in some of the later ones of that series the reverse curve becomes very prominent, notably in Fig. 172. In some of the experiments with cements the reverse, though not quite so prominent as in the case mentioned, yet shows in a marked degree.

To ascertain whether this form of curve follows any of the general laws of flow of water, curves on Fig. 195 were calculated and plotted. It was intended to deduce some expression which would furnish the desired theoretical curve. From the nature of the problem this is seen to be a difficult matter, due both to the indefiniteness of experimental data on capillary flow suitable for this purpose, and to the assumption that the flow of the water through a capillary tube would be the same as the flow of the water through the rock. A suitable comparison was, however, obtained by means of some of the ordinary hydraulic formulae.

The formula, $V = CD^2 H/L \left\{ \frac{t + 10^\circ}{60^\circ} \right\}$ taken from the report of the Massachusetts State Board of Health, representing the flow of water through sand filters, was used as one means of comparison. This formula differs from the ordinary hydraulic formula in that the velocity is proportional to the first power of the head instead of the square root of the same. In this formula:

V = velocity in meters per day.
C = constant = to about 1,000.
D = effective size of sand in millimeters.
H = head.
L = thickness of sand.
T = temperature.

For any given case this formula will reduce to $V = K\,(H/L)^1$ where K = some constant.

If the cross section of the filter remains constant throughout, the velocity of the water passing through it must remain constant. In the case of the stone (Oolitic limestone) under consideration, this area was not quite constant. Some material had to be taken out of the stone in order to insert the 3/8 inch iron piezometer tubes, and to fasten them and to prevent a leakage around the side of the tubes, neat cement was placed around them. This naturally diminished the area of the cross-section. Furthermore, these holes were drilled to various depths, as shown in Plate VI, Fig. 2, consequently the effective area was diminished more and more as we passed from the pressure face to the face open to the air. To put this condition into the formula and note its effect, we know that

$V=Q/F$, where V=velocity
Q=quantity
F=area of section

Substituting this value of V in the formula $V=K(H/L)$ we have $Q/F=K(H/L)$, but Q is constant so that $H=L/F(K_0)$ where K_0=some other constant. The loss of head between any two points, as A and B, will also be proportional to $L/F(K_0)$ so that the loss of head (h_1) between A and B will be

$$h_1=\frac{L_1}{F_1}(K).$$

The loss between the next two holes will be

$$h_2=L_2/F_2(K_0), \text{ etc.}$$

Summing this up, we have $\Sigma h=\Sigma L/F(K_0)$, or $H=K_0\Sigma L/F$ where H total head, hence

$$K_0=\frac{H}{\Sigma\frac{L}{F}}$$

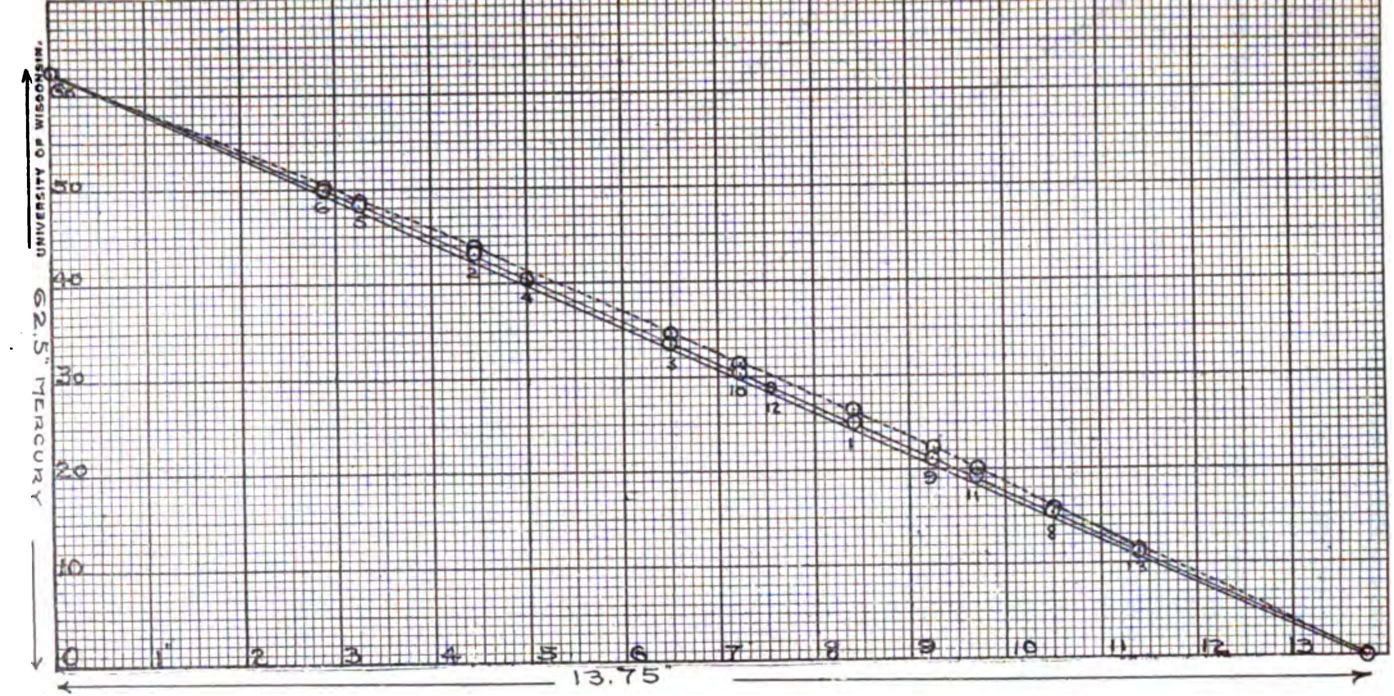
By substituting this value in the above formula, we have the head

$$(h) \text{ lost between any depths of stone}=H\frac{\frac{L}{F}}{\Sigma\frac{L}{F}}$$

From this formula curve M Fig. 195 was determined, and the following shows calculation of the same. The area of a cross-section of the stone is 144 sq. in., and the area assumed to be taken out, by each piezometer tube, is 1 sq. in.

No.	L/F.	heads lost $h=H.\frac{\frac{L}{F}}{\Sigma\frac{L}{F}}$
1.	$\frac{2.85}{144}=.020$	12.50
2.	$\frac{40}{143}=.003$	1.87
3.	$\frac{1.20}{142}=.008$	5.00

.55



- - - - - N.
Center line M.
Bottom line Straight.

Fig. 195.

4. $\frac{\quad}{141} = .004$ 2.50

5. $\frac{1.50}{140} = .011$ 6.87

6. $\frac{.75}{139} = .005$ 3.12

7. $\frac{.25}{138} = .002$ 1.25

8. $\frac{.90}{137} = .007$ 4.37

9. $\frac{.85}{136} = .006$ 3.75

10. $\frac{.45}{135} = .003$ 1.87

11. $\frac{.80}{134} = .006$ 3.75

12. $\frac{.90}{133} = .007$ 4.37

13. $\frac{2.35}{132} = .018$ 11.25

$\Sigma L/F = .100$ Total......62.47

We thus see that according to the equation the curve does n deviate much from a straight line. This deviation is produc by the variation of the area of cross-section and is shown to very slight. It is even greater than it actually should be, sin the area of the stone which was assumed to be taken out by ea tube was 1 sq. in., and this amount was in excess of the actu

To find out the form of curve produced by the ordinary hydrau formula where v varies as the square root of h approximately, t same method was used. We have $V = K\sqrt{h/L}$.

$$\text{or } H/L = V^2/K^2 = \frac{Q^2}{F^2\,K^2} \text{ .... } Q = \text{constant}$$

hence $h = L/F^2\ (K_0)$ where h = head lost between each successi depth.

$$\text{Hence } H = \Sigma L/F^2\ (K_0) \text{ and } K_0 = \frac{\frac{H}{L}}{\Sigma \frac{\quad}{F^2}}$$

The loss of head between any two points $= h = \dfrac{\frac{L}{F^2}}{\Sigma \frac{L}{F^2}}$.

From this equation curve N, Fig. 195, was plotted, the calculation of the same being here inserted.

Area of cross-section of stone = 144 sq. in.

Area taken out by each tube = 1 sq. in.

No.	L/F	head lost $= H \dfrac{\frac{L}{F^2}}{\Sigma \frac{L}{F^2}}$
1.	$\dfrac{2.85}{144^2} = .000137$	12.0
2.	$\dfrac{.40}{143^2} = .000019$	1.6
3.	$\dfrac{1.20}{142^2} = .000060$	5.2
4.	$\dfrac{.55}{141^2} = .000026$	2.3
5.	$\dfrac{1.50^2}{140} = .000076$	6.7
6.	$\dfrac{.75}{139^2} = .000039$	3.4
7.	$\dfrac{.25}{138^2} = .000013$	1.1
8.	$\dfrac{.90}{13} = .000048$	4.1
9.	$\dfrac{.85}{136^2} = .000046$	4.0
10.	$\dfrac{.45}{135^2} = .000025$	2.2
	.80	

11. $\dfrac{\quad}{134^2} = .000045$ 3.9

12. $\dfrac{.90}{133^2} = .000048$ 4.2

13. $\dfrac{2.35}{132^2} = .000135$ 11.8

$\Sigma L/F^2 = .000717$ 62.5

It will be seen that this curve also deviates but a very small amount from the straight line drawn through the extreme points, the deviation being but a trifle more than the preceding curve.

Each of these two curves plotted would fall upon a straight line connecting the two extreme points were it not for the fact that the area of cross-section was variable. The calculations for the effect of this variation were inserted for the purpose of obtaining a direct comparison between the calculated and the experimental curves. From the fact that either of the hydraulic formulae produce the same results, we must infer that the actual theoretical curve applicable to this case will probably also yield the same results. It will be noticed that the change from the flow through ordinary pipes to the flow through sand filters changes the formulae from square root of the head to the first power of the same, and it is possible that the further change from the sand filters to rock may cause a further change in the formulae. Even if this does occur, we will, by holding to our original assumption that the velocity is constant throughout the length of the stone, arrive at the same result above, namely, a straight line.

A comparison of the maximum pressure in the series of curves of the different materials with the straight line drawn through the two extreme points will show a very close agreement. That these recorded readings were influenced to some extent by the clogging of the pores in the stone is evident, but even leaving this out of consideration the agreement is quite striking.

THE EFFECT OF THE INTERNAL PRESSURES.

We have shown thus far, by the experiments before described, that water pressure is transmitted through rock. Having determined this point, the question arises, how does this internal pressure affect the stability of the dam? It will be remembered that the statement was made in the beginning of this paper that the influence of cracks in the dam itself will not be taken into consideration; also that the foundation will be assumed of the same quality as the masonry of the dam itself. By quality here meaning the same power of resistance of pressure, of the same density and porosity. How, then, will this internal water in the dam manifest itself in disturbing the stability of the same?

To best explain the method of estimating the effect of the internal pressure which the writers would suggest, an example may be most satisfactory.

Let us take a cube (Fig. 196.) of sand, say one cubic foot in volume, for simplicity, and immerse in water.

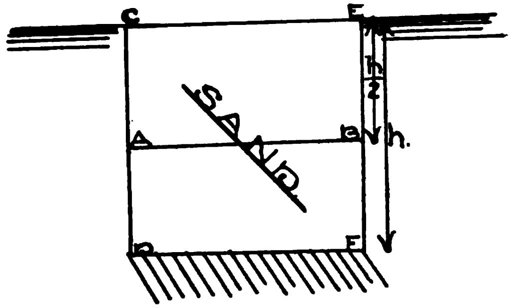


FIG. 196.

Assume for convenience that the whole cube is filled with water, and that the volume of voids in the cube are 30% of the whole volume. Suppose the sand to weigh 125 pounds and a cu. ft. of water 62.5 pounds. Take a section on AB midway between CD. The weight of the sand above $=\frac{125}{2}=62.5\#$. The water displaced by the sand in this upper half $=70\%$ of $\frac{62.5}{2}$ (weight of ½ cubic foot of water), or $21.875\#$, and this is the force with which the sand is buoyed up by the water, leaving an effective weight of the sand of $62.50-21.875=40.625\#$. The same result will be arrived at if we imagine that instead of the plane AB, we pass an irregular surface, of any shape whatever, through the sand in such a manner as not to cut any of the grains. This surface will pass between the grains, and on account of the looseness of the material it is evident that practically all of this surface will be subjected to water pressure. Now considering the upper part of the cube of sand (and water) cut in this way as a free body of approximately ½ cu. ft. in volume, we have as vertical forces acting upon it:

(a) downward

1. its weight $=\frac{1}{2}\times 125=$	$62.50\#$
2. wt. of water $=\frac{1}{2}\times 62.50\times 30\%=$	9.375
Total	71.875

(b) upward

1. water pressure over 1 sq. ft. effective area under a head of $\frac{1}{2}'' = \frac{62.5}{2} = 31.250\#$, leaving a downward resultant of $40.625\#$ the same as obtained by the preceding method.

Now by this latter method it will be seen that the difference of weight of the original block of sand and the saturated block was

produced by the difference of the weight of the water in the cube and the upward pressure, due to a head of ½″ of water. In the upper part of the cube the downward pressure was proportional to the porosity, or to 30% of the volume. On the area of the "irregular" cutting surface we have an upward pressure over the horizontal projection of the whole surface, or 1 sq. ft. The ratio of the downward to the upward pressures is therefore as the relative porosity is to unity.

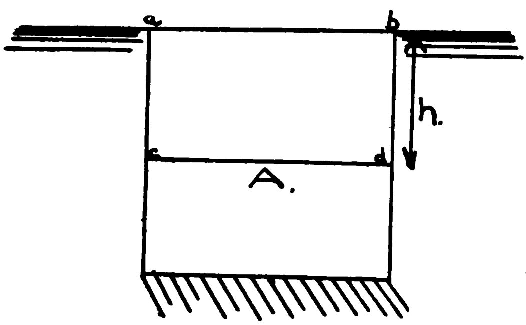


FIG. 197.

Having described the method of estimating the effect of the internal water, numerically, we can now deduce some more general expressions for the same.

Let A = area of a horizontal section.

w_1 = heaviness of dry stone or sand.

w_2 = heaviness of water.

n = vol. of voids ÷ vol of stone (natural).

m = horizontal projection of irregular surface subject to water pressure distant h below top ÷ A.

The vertical forces on abcd =

A. h. w_1 down = wt. of stone abcd.

n. A. h. w_2 down = wt. of water included in abcd.

m. A. h. w_2 up = pressure on face cd.

resultant = $Ahw_1 - [(m-n)Ahw_2]$. (I).

To apply this to a stone, the only question which arises is, can an irregular surface of any kind be made to pass through the stone without cutting any of the grains of the stone itself? This, of course, is impossible, for if it were the case the upper part of the stone could be lifted from the lower without any further resistance than its own weight. Now consider a cube which is so perfectly solid that water cannot penetrate it to any extent. The buoyant effect of water will, of course, have no effect upon it, as it would on the cube of sand if placed in the same position as before assumed. Now go to the other extreme, namely, to the cube of sand which may for the present be considered as a rock of the loosest character. By going from the former to the latter we pass over a series of rocks varying in porosity from the densest materials to the loosest materials, or from the least porous to the most porous. In going from one to the other we change from no effect whatever of the water pressure in the one case to a full effect of the same in the other. It does seem that this change is

not a sudden one, but that it is gradual and that the internal effect of the water pressure changes from zero in the case of the solid up through various pressures depending upon the increasing porosity of the substances to its maximum in the case of loose sand. Just what effect is had in any given case, how much greater the upward than the downward pressure is, it is impossible to say. It is evident, however, that it is some appreciable amount since the ordinary building stones probably lie closer to the sand limit on the one hand than to the perfect solids on the other.

From the formula (I) it will be seen that the subtractive term or the upward pressure varies as (m—n). For a perfect solid both m and n are zero, which causes this subtractive term to disappear. For very loose material both m and n will become some definite amount, as, for instance, in the case of the sand just mentioned, $m=1$ and $n=.30$. For stone, both m and n will be less than for sand, but that the subtractive term will not disappear nor become negative is seen from the fact that m can never be less than n since a plane surface will cut in general a percentage of voids, represented by n, and an irregular surface a much larger percentage.

To apply this method of estimating the effect of the internal water pressure to a dam is but another step. Considering the dam as a single block of stone, of the same texture throughout, the discussion of the single stone above would hold with the exception, however, that the pressure will not be uniform from the front to the back. But other conditions prevail, he dam instead of being a single block consists of separate stones, interlaminated with layers of cement which may be denser or not so dense as the stone itself, depending upon the nature of the materials. Yet this will not change the general results deduced above. They may modify the existing pressures to some extent, increasing them on the one hand or decreasing them on the other. If, however, the cementing material is less dense than the stone employed, as it generally is, it will probably facilitate the passing of the irregular surface as above explained. This follows the general statement that the facility of passing such an irregular surface depends upon the porosity of the substance. The dam then can be assumed to be under the same conditions as the single stone, where, however, its most porous material, as the cement itself, will be the predominant factor in the determination of the ratios of the upward to the downward pressures of the water.

That the layers of cement will influence the height to which the water will stand in the dam is evident. They will act to a certain extent as feeders to the stone itself if the cement is, as has been stated, more porous than the stone.

If, now, these experiments with the stones and the various cement mixtures which were made, and upon which this discussion depends, represent the condition of a stone in a dam, then we are justified in the conclusion that the water will stand in the dam at heights varying from the height of the upper water level on the

up-stream face to that of the lower water level on the down-stream face.

To determine the variation of the height of the water surface in the dam between these two extreme points, the following method has been suggested by Prof. F. E. Turneaure:

Let the figure represent a dam with an approximately vertical upstream face. Take a length of this dam perpendicular to the plane of the paper equal to W.

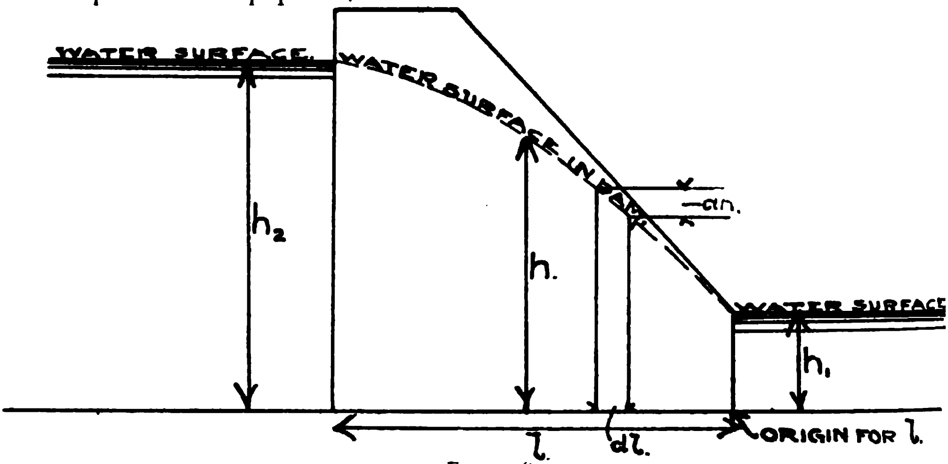


FIG. 198.

Now, according to the generally accepted law of flow through porous material, the velocity at any point $= v = \frac{dh}{dl}.K$

where dh = head of water
dl = length of its path
and K = some constant

Now if Q = quantity of water flowing, we have $v = \frac{Q}{W.h}$ where Q is constant,

$$\text{hence } \frac{dh}{dl}.K = \frac{Q}{W.h} \text{ or}$$

$$h.\ dh = dl.\frac{Q.}{WK}$$

or integrating from h_1 to h we have

$$\tfrac{1}{2}(h^2 - h_1^2) = l\frac{Q}{WK} \text{ or}$$

$$l = \frac{\tfrac{1}{2}(h^2 - h_1^2).WK}{Q}$$

That is, the dotted curve in the above figure is a parabola where the axis is horizontal.

In the experiments made upon the small blocks of stone, the curves show that the pressures are likely to lie below the theoretical curve. This would, however, strictly be a piece of the above parabola if the difference in pressure at the top and the bottom of the stone were taken into consideration. Neglecting these, it becomes a straight line, as previously shown.

In a dam we may, for practical purpose, likewise assume the curve of the water surface below the theoretical line. This may not give us the maximum effect of the internal water pressure, but on account of the indefiniteness of the application of this pressure in the different kinds of stones, we may be warranted in the assumption that the pressure varies between the surface of the water on the upstream face and the surface of the water on the downstream as a straight line drawn between these points.

This may be considered as the effective head, and the average of it over the whole base would then be in the case of a rectangular dam one-half of the maximum. To apply this prèssure, the same method would be resorted to as described in the case of the single stone. The resultant downward pressure would depend upon the ratio assumed, namely, the area of voids to the total area which would result by the passing of the warped surface through the dam. From the indefiniteness of the problem it will probably be the best policy to assume the maximum case, namely, that the irregular surface cuts no grains of the stone, since this will always be on the side of safety.

Then the resultant downward pressure on any surface will be the weight of the stone above, plus the weight of the water filling the voids above the section, minus the upward pressure of the average head of water over the whole area.

To consider the change in the ordinary formulae for the design of dams which this would produce has not been the aim of this paper. With the foregoing deductions and with the aid of the formulae deduced by Mr. Van Buren in the article referred to at the beginning of this discussion (T. A. S. C. E., Vol. 34) this seems only a simple matter.

CONCLUSIONS.

We have shown in the preceding discussion that water pressure can be and is transmitted through ordinary stones. That it is transmitted through actual dams is a fact which becomes apparent when the appearance of moisture on the down stream side of the dam is taken into consideration. We have further shown how the presence of this internal water may affect the stability of the dam, neglecting the fact that cracks or fissures or a pervious foundation may also cause a further lack of stability. We have tried to show how this internal pressure shall be taken into consideration in the design of dams. Perhaps some later experiments may give a more definite knowledge in regard to the vari-

ation of pressures for a wider range of building stones, or possibly some determinations of the pressures in actual dams may be forthcoming. It was the intention of the writers to complete the series of experiments by a test upon a constructed dam, but the great distance of any suitable masonry dam from this point prevented this.

Now as to some of the possible means for reducing or eliminating the effect of the internal water pressure.

Several dams have been constructed utilizing a system of interior drainage as a relief for the internal pressure. That this method, if properly used, may be effective in the reduction of this pressure seems evident.

That the effect of sediment in the water may also be of service for the relief of the interior pressure is shown by many of the curves of pressures included in this paper.

We must, however, consider that this clogging does not immediately reduce the pressure, and in the case of filling the reservoir the water would probably exert its maximum pressure for some time before it would be reduced, and this will occur as often, though probably not in the maximum degree, each time the reservoir is emptied and filled again.

The application of some impervious coating, as neat cement or asphalt, on the upstream side of a dam will further aid in effectively reducing the interior pressures. It has already been shown that a thin coat of neat Portland cement, applied on the surface of a stone, reduces the pressures to a remarkable extent, and it would seem that a coating, of say an inch or more, applied to a dam would be very effective if this could be applied in such a manner as to furnish a certainty of its remaining in the position.

Where the foundation of a dam rests upon a base of some pervious material or rock which may be as porous or more so than the dam itself, it would be necessary to coat this with a similar material for some distance above the dam if the internal pressure is to be partially eliminated. We have here the same condition as in the dam, the water, however, being probably able to exert a greater pressure than in the dam itself, depending on the nature of the underlying materials. Were the dam alone to be coated with an impenetrable coating, we would have a condition as represented in the Fig. 199, a maximum pressure on the heel and zero on the toe, which would affect the stability of the dam to nearly as great an extent as though the coating were absent. If, however, the bottom surface is paved upstream from the dam, then a much greater reduction of pressure is probably obtained. In Fig. 200 this is quite clearly shown. Where the upstream face of the dam is only paved, we would have a pressure

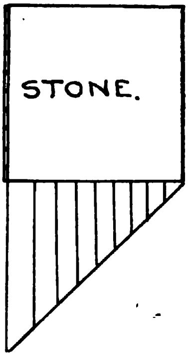


FIG. 199.

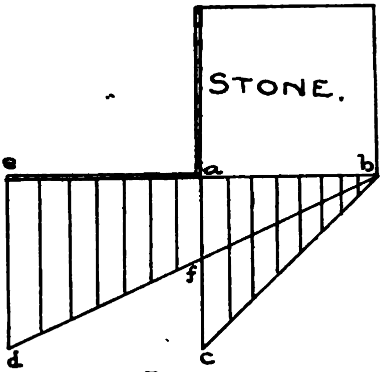


FIG. 200.

at the base varying approximately as the triangle acb. If the paving extends from a to e, the pressures would probably be shown by the triangle edb. We have, then, as an effective pressure on the dam itself the area of the triangle abf. The original pressures of abc have been considerably reduced. How far this paving should extend upstream must be determined from the conditions of the underlying materials. Evidently the greater the length of it the more effective does it become in reducing the pressures.

The effect of the internal water can therefore be removed to some extent, but that some water will remain in the dam which must be taken into consideration in its design is evident. Besides, the probability of a flawless application of the coats of cement is too remote, and consideration must therefore be had for it.

Someone has suggested that a coating of iron would be effective in keeping the water out of the dam. If this is applied in the method outlined in the case of neat Portland cement by paving both the pressure side and the bottom directly in front of the dam, it is very evident that this would be the most effective means of reducing the pressure.

For many of the valuable suggestions offered, as well as the aid furnished to successfully conduct this series of experiments, the writers wish to express their thanks to Professors Turneaure and Maurer of the engineering department of the University of Wisconsin.

DISCUSSION.

Mr. Bainbridge: I would like to ask how many pipes were used in the experiment and what was their extreme length?

Mr. Broenniman: We had one five or six feet long; most of our curves from the pipes were about 22 to 24 inches long.

Mr. Bainbridge: What was the hydrostatic pressure used?

Mr. Broenniman: Pressure upon the face?

Mr. Bainbridge: Yes.

Mr. Broenniman: That was 62.5 inches mercury.

Mr. Bainbridge: What is that in pounds, or per square inch?

Mr. Broenniman; About 30 pounds.

Mr. Beardsley: Was there any test made of the fineness of the Portland cement?

Mr. Broenniman: We did not test the fineness of the cement, but we took the size of sand that was used in the sand mixture in the cement.

Mr. Johnston: There is one point in connection with the presence of water in cement mortar I have heard suggested that is rather interesting. I first heard of it in connection with the breaking of briquettes of neat Portland cement, which had been submerged in water for a greater or less duration of time. The briquettes had been kept under water for seven or more days and then taken from the water and broken, a certain number being broken in one, two, three, four, five and six hours and so on up to a greater length of time. A series of experiments of this kind was made by Mr. Newberry, the chemist of the Alpha cement works; the strength of the briquettes fell off very rapidly with the length of time they had been out of the water up to a given period, when the strength commenced to increase again; the series he showed me broke at 600 to 700 pounds when taken out of water, and from two to three hundred pounds after being out fourteen or fifteen hours; and then the strength increased afterwards until it got back to where it was when immediately taken from the water. He made these observations in connection with the breaking of briquettes each succeeding hour after the briquettes were taken from the water wet, and they came back to the strength they had immediately upon being taken out of the water. He noticed also that as each succeeding set was broken, the wet spot at center of briquettes was smaller until it finally disappeared. He connected the two facts, and drew the inference that the varying degree of moisture in the internal part of the briquettes caused the varying strengh of the briquettes. That view of the matter is somewhat interesting whether it is true or not; it suggests the effect that varying degree of moisture might have in cement or cement mortars.

Mr. Curtis: Does that same rule hold true as to all ages of cement?

Mr. Johnston: I do not know as it is true with reference to all ages, but the inference is it would be.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSLATIONS AND PERIODICALS.

HIGH BUILDINGS.

(From "Wind pressure in the St. Louis Tornado," by Julius Baier, Mem. Am. Soc. C.E., Trans. Am. Soc. C. E., Vol. XXIII, No. 1, Page 107.)

Much of the destruction in St. Louis was undoubtedly caused by an intensity of wind pressure that it would be neither possible nor expedient to provide against in ordinary structures, but much of it was also due to weak construction. A general observance of the ordinary requirements for good building work would largely decrease the damage due to such storms. The great amount of explosive action was largely due to the comparative weakness of ordinary walls against pressure exerted from the inside of buildings. A more efficient anchorage of the walls might limit this explosive action to the windows. In numerous instances the windows were blown in on the windward side, while the entire wall was blown out on the leeward side. Brick walls are materially stronger if well bonded with the vertical joints filled with mortar, and a wall laid in cement will undoubtedly withstand a greater lateral force than one laid in lime mortar. It is worth nothing that the walls of the buildings of the Union Depot Railway plant left standing were laid in cement, while the other buildings, which were entirely wrecked, had walls laid with lime mortar. The great damage done to the churches calls attention to the great exposure of the steep and lofty roofs supported on high and comparatively thin and unbraced walls. Heavier buttresses or independent steel column supports, with bracing for the roof trusses, would materially increase the safety of such structures. In general, the buildings with large areas of unbraced walls have suffered most.

The lofty office buildings common to the large cities represent an expenditure of money that justifies careful provision against any destruction that may arise from even exceptional wind pressures.

The question as to what would be the effect of a tornado on these high buildings is one that has probably occurred to every engineer and architect.

The periodic prevalence of these storms emphasized by the recent calamity in St.Louis, by the destruction in Louisville in 1890, and by a similar storm in Little Rock in 1894, and in Kansas City in 1886, gives a somewhat broader public interest to this question, and appears to call for its serious consideration. The

evidence of the work of the wind in St.Louis suggests as an immediate answer to the question that it will depend largely upon the nature of the metal framework in the building.

The high office building represents the outcome of an evolution in architectural and constructive design dictated by the commercial necessities of the age. The tendency to the concentration of business interests within small areas, the excessive high values of land, and the necessity of realizing an adequate return on the investment, demand a building with many floors and the maximum rentable space on each floor—a high building with thin walls. The replacement of the heavy exterior masonry by the lighter veneer or curtain walls and the consequent gain in available floor space has been made possible by the use of an iron or steel frame work, primarily introduced to carry the vertical loads only, but gradually modified and strengthened in accordance with an increasing recognition of the need of providing lateral strength and stiffness against the wind and other destructive forces. There still exists, however, a great diversity in the treatment of this feature of the design.

The metal framework of a building is somewhat generally called the "skeleton" and sometimes a "cage." If both of these terms are to be retained in this special sense, a convenient distinction can be made by some restriction in their use suggested by the words themselves.

Skeleton is a term clearly descriptive of that type of construction to which it was first applied, a simple framework of columns and beams whose efficiency is dependent largely on the existence of exterior walls and partitions which brace the building and hold the framework in position, just as the utility of the human skeleton is dependent on the covering of sinews and muscles that hold the component parts together. On the other hand, the light framework of an ordinary wire cage bound into one compact unit is suggestive of an inherent strength and elastic resistance that renders any covering an incident rather than a necessity. Cage is a term peculiarly descriptive of that type of construction represented by the most advanced and approved practice, a framework of columns and beams, spliced at the joints, riveted at the connections, stiffened by an efficient bracing of rods, portals and gussets that makes it independently safe against any external force, leaving the thin and light exterior walls with no duty except that of providing protection and ornamentation for the building. The effect of an extreme wind pressure on a high office building with curtain walls must depend largely on the extent to which the frame of that building partakes of the nature of the skeleton type or the cage type of construction.

The possible work of destruction of a tornado may appear more clearly if, as Ferrel suggests, the column of rapidly revolving air is likened to a tall flue, with heated and rarefied air in its interior. If the access of air is cut off from the lower central part by the

shell of gyrating air extending down to the surface, the lateral currents and ascending currents in the interior will be of no violence, but with a somewhat free access of air below into the rarefied interior, on account of a decrease by friction of the gyratory velocity near the surface, the inrush of lateral air currents becomes extremely violent and the velocity of the uprush of air in the interior becomes enormous. In the former case the destruction is mainly due to the excessively high gyratory velocities; the destruction is complete, but the path narrow. It is the condition that may prevail in open country with but few objects to destroy the energy of the tornado. In the latter case the destruction is largely due to the violent lateral inrushing currents. The path is wider, and the force not so extreme. It is the condition which must prevail in any compactly built city, owing to the great friction of air arising from the irregularities due to the many buildings.

The first high isolated building encountered will feel the full force of the gyratory velocity, but the resistance of the building destroys this velocity and the work of destruction wrought on that building must represent an equivalent diminution of energy in the lower section of the tornado, which can only be renewed by its further unobstructed progress during such appreciable time as is necessary to restore the gyratory velocity. A succession of high buildings will prevent such recovery of velocity.

The destructive power of a tornado on massive building work due to these excessively high velocities is therefore soon exhausted, but the wind pressure due to the violent currents rushing in from all sides are only intensified thereby.

It a tornadic storm with a well-developed whirl should pass through the section of any city containing very high buildings, the general level of the top of the lower buildings becomes equivalent to the ground surface, and it seems fair to assume as the result the same general action that has been found near the surface, modified or intensified in its irregularity according to the degree of uniformity in the general height of the majority of the buildings. There may be the extreme pressures due to the gyratory velocity of the tornado proper exerted over a limited area and for a very limited time. There will be a far wider zone of lateral inrushing winds at high velocities lasting throughout the progress of the tornado and attended by the additional complications that may arise due to the concentration of air currents in the deep valleys formed by the streets between the buildings. The probable result would be an extremely variable and intense action of the wind about the tops of the lower buildings, the same action concentrated locally at about that level on the higher buildings, accompanied with a general severe pressure over the entire exposed area of the latter, this latter pressure probably being a maximum near the top or at least some distance above the general level where the friction is not so great.

A characteristic feature of the St. Louis tornado, and one which, judging from records and published views, is also common to other tornadoes and violent huricanes, is the general destruction of the ordinary brick and stone walls. Regardless of the sequence in which they may explode outward or are blown inward, and of a possible difference of opinion as to whether the explosion is due to a plenum, a vacuum or to a suction, the essential fact remains that the walls do very generally fall.

Assuming a similar action of the wind, the buildings of an average height will probably have the walls at the top or exposed corners destroyed, or, if particularly weak, may be shaken down. The buildings above the average height would be very liable to have part of the walls at any level blown in or taken out. An office building with the curtain walls of one or more stories removed would support the remaining enveloped superstructure precisely in the manner of the grain elevator before it was struck by the storm.

In view of these facts it appears to the author rational to assume:

First—That the safety and interests of the community and of the owner of the building require a recognition of a wind pressure of at least 30 lbs. per square foot against the exposed surface of the building, with an additional local provision of 50 lbs. for several stories near the top; and that this amount should be safely taken care of by some positive and definite provision in the construction of the frame.

Second—That the vast interest at stake, the amount of capital invested and the comparatively small additional expense necessary would suggest to the owner the desirability of increasing the provision to 40 lbs. per square foot.

Third—That the other uncertain elements of safety due to the ultimate strength of the material, the inertia of the mass, and the bracing effect of walls and partitions, should be recognized only as providing against the uncertain and possible higher pressure of the wind which may occur.

The chief justification of much that seems bold or questionable in the construction of some high buildings lies in the fact that, as yet, none have failed. If the safety of such great structures is to be determined entirely by the logic of the fitness of the survivor, based on a brief and favorable experience, rather than by a rigid analysis, by tried and accepted principles of engineering design, it may ultimately lead to some very deplorable results.

By such a test the little summer pavilion in Lafayette Park must take precedence over the approach to the Eads Bridge, for it survived the tornado and is standing yet.

"THE USE OF LIME AND LIMESTONE SCREENINGS IN CEMENT MORTARS."

(Extracts from Report of Col. Lydecker, Appendix LL of Report of Chief of Engineers, U. S. A., for 1896.)

The portion of Col. Lydecker's Report relating to tests of materials was prepared by Asst. Eng. L. C. Sabin. The materials tested were to be used in the construction of the 800-foot lock in the St. Marys river at Sault Ste Marie, Mich.

SERIES 20.—*Limestone screenings; effect of varying fineness on its value for use with Portland cement.*

Reference.	Sand. Kind.	Sand. Fineness.	Sand. Parts to 1 of cement.	Water as per cent of dry ingredients.	Date made.	Age.	Tensile strength. Mean.	Tensile strength. Highest.	Tensile strength. Lowest.	Tensile strength. Number averaged.	Molder.	Tank.	Weight of 10 briquettes dried by wiping just before breaking.	Remarks.
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	
					1892.		*Lbs*	*Lbs*	*Lbs*				*Grams.*	
1	L. S.	10–20	3	10.7	Mar. 31	6 months	716	757	685	5	N	C	1,534	Trifle dry.
2	L. S.	10–20	3	11.1	....do..	6 months	721	827	645	5	N	C		Still trifle dry
3	L. S.	20–30	3	12.5	....do .	6 months	657	725	600	10	N	C	1 521	Trifle dry, same as No. 1.
4	L. S.	30–40	3	13.3	....do ...	6 months	633	662	598	10	N	C	1,500	Do.
5	L. S.	40–50	3	14.8	....do ...	6 months	516	584	484	10	N	C	1,466	Do.
6	L. S.	Pass. 50	3	17.9	....do ...	6 months	403	450	356	10	N	C	1,407	Trifle dry; shrank away from molds.
7	L. S.	10–20	3	12.5	Apr. 1	2 years..	812	860	775	6	N	C	....	
8	L. S.	20–30	3	14.1	....do ...	2 years..	754	808	679	5	N	C	....	
9	L. S.	30–40	3	15	....do ..	2 years..	656	689	615	5	N	C	....	
10	L. S.	40–80	3	17.2 16.7	....do ..	2 years..	516	538	492	5	N	C	....	3 trifle moist; 2 O. K.
11	L. S.	Pass. 50	3	19.6 19.3	....do ...	2 years..	488	496	476	5	N	C	....	Do.
12	L. S.	10–20	3	12.5	....do ...	4 years..	845	906	795	4	N	C	....	
13	L. S.	20–30	3	14.1	....do ...	4 years..	782	860	725	5	N	C	....	
14	L. S.	30–40	3	15	....do ...	4 years..	714	737	686	5	N	C	....	
15	L. S.	40–80	3	17.2 16.7	....do ..	4 years..	571	626	547	5	N	C	....	2 trifle moist; 3 O. K.
16	L. S.	Pass. 50	3	19.6 19.3	....do ...	4 years .	516	550	485	5	N	C	....	Do.

Series 20.—Varying fineness of limestone screenings used in mortar.—The four-year results have been added to this table. The mor-

tars composed of the several samples of sand have all increased in strength without changing their relative positions.

Series 60.—The use of lime with cement.—Table 3 indicates that the addition to a 1 to 3 Portland cement mortar of an amount of lime in the form of paste equal to 10 per cent of the cement slightly increases the early strength of the mortar, whether it be stored in dry air or in moist sand; that such an addition of lime results in an increased strength at one year when the mortar is stored in damp sand, but gives a lower result when the mortar is allowed to harden in dry air. It also appears that 10 per cent

Series 60.—*The use of lime with cement.*

Table 3.—LIME PASTE WITH PORTLAND CEMENT.

[Molder, S.]

Reference.	Cement (grams): Brand, X; sample, 41s.	Lime. Grams of lime paste.	Lime. Grams of lime in paste given in column *b*.	Lime. Amount of lime expressed as per cent of total lime and cement.	Sand Kind.	Sand Grams.	Water (cubic centimeters).	Volume mortar.	Date made (May, 1895).	Age.	Tensile strength. Mean.	Tensile strength. Highest.	Tensile strength. Lowest.	Number averaged.	Stored.	Time in molds.	Weight per briquette before breaking.
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*
											Lbs.	*Lbs.*	*Lbs.*			*hrs.*	*gms.*
1	200	0	0	0	Point aux Pins passing No. 10 sieve.	600	100	405	16	28 days	201	216	176	5	Dry air	14	.....
2	200	54	20	8		600	76	415	16	28 days	242	280	203	5	Dry air	12	.....
3	180	54	20	10		600	70	395	16	28 days	238	258	210	5	Dry air	12	.....
4	150	134	50	25		600	46	410	16	28 days	168	180	152	5	Dry air	8	.....
5	100	268	100	50		600	00	425	16	28 days	57	74	42	5	Dry air	8	.....
6	200	0	0	0		600	100	400	17	3 mos	236	276	204	5	Dry air	13	.....
7	200	54	20	8		600	76	410	17	3 mos	265	304	232	5	Dry air	10	.....
8	180	54	20	10		600	70	400	17	3 mos	264	274	238	5	Dry air	10	.....
9	150	134	50	25		600	46	415	17	3 mos	171	181	148	5	Dry air	10	.....
10	100	268	100	50		600	00	435	17	3 mos	70	84	56	5	Dry air	9	.....
11	200	0	0	0		600	100	....	18	1 year	384	432	352	5	Dry air	12½	.....
12	200	54	20	8		600	76	....	18	1 year	377	446	298	5	Dry air	10½	.....
13	180	54	20	10		600	70	....	18	1 year	317	386	267	5	Dry air	10½	.....
14	150	134	50	25		600	46	....	18	1 year	215	234	200	5	Dry air	9	.....
15	100	268	100	50		600	00	....	18	1 year	98	112	87	5	Dry air	9	.....
16	200	0	0	0		600	100	400	16	28 days	294	319	266	5	Damp sand	14	.....
17	200	54	20	8		600	76	410	16	28 days	330	354	310	5	Damp sand	12	.....
18	180	54	20	10		600	70	395	16	28 days	309	333	288	5	Damp sand	12	.....
19	150	134	50	25		600	46	410	16	28 days	238	264	211	5	Damp sand	8	.....
20	100	268	100	50		600	00	430	16	28 days	95	102	83	5	Damp sand	8	.....
21	200	0	0	0		600	100	400	17	3 mos	350	370	330	5	Damp sand	13	141
22	200	54	20	8		600	76	415	17	3 mos	410	444	390	5	Damp sand	10	146
23	180	54	20	10		600	70	400	17	3 mos	398	409	380	5	Damp sand	10	145
24	150	134	50	25		600	46	410	17	3 mos	309	330	288	5	Damp sand	10	140
25	100	268	100	50		600	00	435	17	3 mos	125	148	110	5	Damp sand	9	140
26	200	0	0	0		600	100	....	18	1 year	430	450	396	5	Damp sand	12½	.....
27	200	54	20	8		600	76	....	18	1 year	445	468	426	5	Damp sand	10½	.....
28	180	54	20	10		600	70	....	18	1 year	442	460	416	5	Damp sand	10½	.....
29	150	134	50	25		600	46	....	18	1 year	332	350	310	5	Damp sand	9	.....
30	100	268	100	50		600	00	....	18	1 year	171	174	162	5	Damp sand	9	.....

of the cement may be replaced by lime in the form of paste without decreasing the strength given at one year if the mortar hardens in moist sand. When 25 or 50 per cent of the cement is replaced by lime, the resulting strength is considerably diminished.

Tables 4, 5 and 6 indicate that for this brand of natural cement as much as 25 per cent of the cement may be replaced by lime in the form of paste and an increased strength will result, unless the mortar hardens in dry air, in which case this amount of lime is detrimental. Smaller percentages of lime appear to be very beneficial. Further results showing the effect of lime on cement mortars are given in series 73.

SERIES 60.—*The use of lime with cement*—Continued.

TABLE 4.—LIME PASTE WITH NATURAL CEMENT.

[Lime paste made August 5, 1895.]

		Lime.			Sand.					Tensile strength.						
Reference.	Cement (grams), Brand An, Sample L.	Grams of lime paste.	Grams of lime in paste given in column *b*.	Amount of lime expressed as per cent of total lime and cement.	Kind.	Grams.	Water (cubic centimeters).	Date made (August, 1895).	Age.	Mean.	Highest.	Lowest.	Number averaged.	Stored.	Time in molds (hours).	Molder.
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
										Lbs.	*Lbs.*	*Lbs.*				
1	200	0	0	0	Point aux Pins, passing No. 10 sieve.	600	100	14	28 days	154	180	128	5	Tank I	5½	M
*2	200	60	20	8		600	70	14	28 days	179	190	163	5	Tank I	21	M
†3	180	60	20	10		600	60	14	28 days	167	177	144	5	Tank I	20	M
‡4	150	150	50	25		600	20	14	28 days	138	162	116	5	Tank I	17	M
§5	100	300	100	50		600	0	14	28 days	38	43	34	5	Tank I	40	M
6	200	0	0	0		600	100	15	3 mos	222	257	196	10	Tank I	5½	M
*7	200	60	20	8		600	70	15	3 mos	301	328	254	10	Tank I	6	M
†8	180	60	20	10		600	60	15	3 mos	319	344	300	10	Tank I	20	M
‡9	150	150	50	25		600	20	15	3 mos	293	314	269	10	Tank I	17	M
§10	100	300	100	50		600	0	15	3 mos	79	98	64	10	Tank I	16	M
11	200	0	0	0		600	100	16	3 mos	267	306	252	5	Damp sand	5	M
*12	200	60	20	8		600	70	16	3 mos	344	378	306	5	Damp sand	21	M
†13	180	60	20	10		600	60	16	3 mos	327	346	320	5	Damp sand	20	M
‡14	150	150	50	25		600	20	16	3 mos	318	356	296	5	Damp sand	17	M
§15	100	300	100	50		600	0	16	3 mos	93	102	76	5	Damp sand	16	M
16	200	0	0	0		600	100	16	3 mos	310	336	274	5	Dry air	5	M
*17	200	60	20	8		600	70	16	3 mos	338	360	316	5	Dry air	21	M
†18	180	60	20	10		600	60	16	3 mos	359	384	333	5	Dry air	20	M
‡19	150	150	50	25		600	20	16	3 mos	251	274	226	5	Dry air	17	M
§20	100	300	100	50		600	0	16	3 mos	69	104	48	5	Dry air	16	M

* Lime paste added to cement; trifle plastic.
† Lime paste replacing cement; trifle plastic.
‡ Lime paste replacing cement; plastic.
§ Lime paste replacing cement; too moist; trifle sticky.

SERIES 60.—*The use of lime with cement*—Continued.

TABLE 5.—LIME PASTE WITH NATURAL CEMENT.

[Lime paste made August 5, 1895.]

Reference.	Cement (grams), Brand An, Sample L.	Lime. Grams of lime paste.	Lime. Grams of lime in paste given in column *b*.	Lime. Amount of lime expressed as per cent of total lime and cement.	Sand. Kind.	Sand. Grams.	Water (cubic centimeters).	Volume mortar.	Date made (October, 1895).	Age.	Tensile strength. Mean.	Tensile strength. Highest.	Tensile strength. Lowest.	Tensile strength. Number averaged.	Stored.	Time in molds (hours).	Molder.
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*
											Lbs.	*Lbs.*	*Lbs.*				
1	200	0	0	0	Point aux Pins, passing No. 10 sieve.	600	100	....	10	28 days.	182	212	158	5	Dry air	21⅛	S
* 2	200	60	20	8	Point aux Pins, passing No. 10 sieve.	600	70	....	10	28 days.	165	181	124	5	Dry air	20⅛	S
† 3	180	60	20	10	Point aux Pins, passing No. 10 sieve.	600	60	....	10	28 days.	146	165	122	5	Dry air	19⅛	S
‡ 4	150	150	50	25	Point aux Pins, passing No. 10 sieve.	600	20	....	10	28 days.	154	176	122	5	Dry air	17⅛	S
§ 5	100	300	100	50	Point aux Pins, passing No. 10 sieve.	600	0	....	10	28 days.	42	47	40	4	Dry air	16⅛	S
6	200	0	0	0	Point aux Pins, passing No. 10 sieve.	600	100	....	10	28 days.	106	122	96	5	Damp sand	21⅛	S
* 7	200	60	20	8	Point aux Pins, passing No. 10 sieve.	600	70	....	10	28 days.	109	115	102	5	Damp sand	20⅛	S
† 8	180	60	20	10	Point aux Pins, passing No. 10 sieve.	600	60	....	10	28 days.	118	122	114	5	Damp sand	19⅛	S
‡ 9	150	150	50	25	Point aux Pins, passing No. 10 sieve.	600	20	....	10	28 days.	93	97	87	5	Damp sand	17⅛	S
§10	100	300	100	50	Point aux Pins, passing No. 10 sieve.	600	0	....	10	28 days.	13	15	12	2	Damp sand	16⅛	S
11	200	0	0	0	Point aux Pins, passing No. 10 sieve.	600	100	420	12	3 mos	157	179	136	5	Dry air	22⅛	S
*12	200	60	20	8	Point aux Pins, passing No. 10 sieve.	600	70	425	12	3 mos	166	200	128	5	Dry air	21⅛	S
†13	180	60	20	10	Point aux Pins, passing No. 10 sieve.	600	60	420	12	3 mos	194	216	133	5	Dry air	20⅛	S
‡14	150	150	50	25	Point aux Pins, passing No. 10 sieve.	600	20	425	12	3 mos	162	185	134	5	Dry air	18	S
§‖15	100	300	100	50	Point aux Pins, passing No. 10 sieve.	600	0	460	12	3 mos	55	72	43	5	Dry air	23	S
16	200	0	0	0	Point aux Pins, passing No. 10 sieve.	600	100	420	12	3 mos	222	243	210	5	Damp sand	22⅛	S
*17	200	60	20	8	Point aux Pins, passing No. 10 sieve.	600	70	425	12	3 mos	297	336	267	5	Damp sand	21⅛	S
†18	180	60	20	10	Point aux Pins, passing No. 10 sieve.	600	60	420	12	3 mos	284	319	254	5	Damp sand	20⅛	S
‡19	150	150	50	25	Point aux Pins, passing No. 10 sieve.	600	20	420	12	3 mos	224	262	130	5	Damp sand	13	S
§20	100	300	100	50	Point aux Pins, passing No. 10 sieve.	600	0	470	12	3 mos	70	73	60	5	Damp sand	23	S

TABLE 6.—LIME PASTE WITH NATURAL CEMENT.

[Lime paste made August 5, 1895.]

1	200	0	0	0	Point aux Pins, passing No. 10 sieve.	600	146	460	17	3 mos	54	66	42	5	Dry air	22	S
2	200	60	20	8	Point aux Pins, passing No. 10 sieve.	600	116	470	17	3 mos	69	87	50	5	Dry air	21	S
3	180	60	20	10	Point aux Pins, passing No. 10 sieve.	600	110	460	17	3 mos	67	72	57	5	Dry air	20	S
4	150	150	50	25	Point aux Pins, passing No. 10 sieve.	600	66	460	17	3 mos	78	87	68	4	Dry air	17	S
5	100	300	100	50	Point aux Pins, passing No. 10 sieve.	600	0	470	17	3 mos	65	72	56	4	Dry air	16	S
6	200	0	0	0	Point aux Pins, passing No. 10 sieve.	600	146	460	17	3 mos	111	120	96	5	Damp sand	22	S
7	200	60	20	8	Point aux Pins, passing No. 10 sieve.	600	116	475	17	3 mos	109	117	102	5	Damp sand	21	S
8	180	60	20	10	Point aux Pins, passing No. 10 sieve.	600	110	460	17	3 mos	129	148	106	5	Damp sand	20	S
9	150	150	50	25	Point aux Pins, passing No. 10 sieve.	600	66	460	17	3 mos	103	113	93	5	Damp sand	17	S
10	100	300	100	50	Point aux Pins, passing No. 10 sieve.	600	0	470	17	3 mos	56	61	54	5	Damp sand	16	S

* Lime paste added to cement; trifle plastic.
† Lime paste replacing cement; trifle plastic.
‡ Lime paste replacing cement; plastic.
§ Lime paste replacing cement; too moist; trifle sticky.
‖ Fine surface cracks.

NOTE.—All appeared same consistency, quite moist; would not pack in molds. Plasticity of mortar increased with addition of lime paste.

Series 73.—*Adhesion of cement mortar to brick. Lime paste with cement.*

Table 1.—TENSILE STRENGTH OF MORTAR ALONE, PORTLAND AND NATURAL.

Reference.	Cement (grams).	Lime paste.						Point Aux Pins sand passing No. 10 sieve.		Water added (cubic centimeters).	Date made.	Age.	Tensile strength.				Stored.	Time in molds (hours).	Molder.	Cement.	
		Date slacked (March, 1895).	Grams.	Lime contained (grams).	Water contained (grams).	Lime paste as per cent of total cement and lime paste.	Lime in paste as per cent of lime plus cement.	Grams.	Parts to 1 of cement and lime paste.				Mean.	Highest.	Lowest.	Number averaged.				Portland or natural.	Brand and sample.
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
											1895.		Lbs.	Lbs.	Lbs.						
1	120	21	0	0	0	0	0	480	4	100	Mar. 30	28 days	100	113	90	5	Dry air	20[illegible]	S.	Portland	X, 41 S.
2	120	21	40	14	26	25	10	480	3	84	....do	28 days	95	112	82	5	....do	29[illegible]	S.	....do	X, 41 S.
3	105	21	35	12	23	25	10	560	4	90	....do	28 days	82	88	78	5	....do	28[illegible]	S.	....do	X, 41 S.
4	70	21	70	24	46	50	25	560	4	70	....do	28 days	42	50	35	4	....do	26	S.	....do	X, 41 S.
5	....	21	140	48	92	100	100	560	4	16	....do	28 days	52	61	47	5	....do	41[illegible]	S.	None	
6	120	21	0	0	0	0	0	480	4	100	....do	3 months	97	121	68	5	....do	30[illegible]	S.	Portland	X, 41 S.
7	120	21	40	14	26	25	10	480	3	84	....do	3 months	90	124	62	5	....do	29[illegible]	S.	....do	X, 41 S.
8	105	21	35	12	23	25	10	560	4	90	....do	3 months	101	136	68	5	....do	28[illegible]	S.	....do	X, 41 S.
9	70	21	70	24	46	50	25	560	4	70	....do	3 months	46	50	42	4	....do	26	S.	....do	X, 41 S.
10	....	21	140	48	92	100	100	560	4	16	....do	3 months	59	65	48	5	....do	41[illegible]	S.	None	
11	120	21	0	0	0	0	0	480	4	110	Apr. 1	28 days	11	16	3	4	....do	23	S.	Natural.	Gn., LL.
12	120	21	40	14	26	25	10	480	3	94	....do	28 days	32	36	30	5	....do	22	S.	....do	Gn., LL.
13	105	21	35	12	23	25	10	560	4	98	....do	28 days	23	26	18	5	....do	28[illegible]	S.	....do	Gn., LL.
14	70	21	70	24	46	50	25	560	4	77	....do	28 days	29	32	26	5	....do	25[illegible]	S.	....do	Gn., LL.
15	....	21	140	48	92	100	100	560	4	16	....do	28 days	56	75	48	5	....do	40	S.	None	
16	120	21	0	0	0	0	0	480	4	110	....do	3 months	18	28	8	2	....do	23	S.	Natural.	Gn., LL.
17	120	21	40	14	26	25	10	480	3	94	....do	3 months	38	42	35	5	....do	22	S.	....do	Gn., LL.
18	105	21	35	12	23	25	10	560	4	98	....do	3 months	21	30	16	3	....do	28[illegible]	S.	....do	Gn., LL.
19	70	21	70	24	46	50	25	560	4	77	....do	3 months	22	24	20	4	....do	25[illegible]	S.	....do	Gn , LL.
20	....	21	140	48	92	100	100	560	4	16	....do	3 months	68	84	59	5	....do	40	S.	None	

Remark.—Consistency about same as mason's mortar, moist.

SERIES 73.—*Adhesion of cement mortar to brick. Lime paste with cement*—Continued.

TABLE 7.—PORTLAND AND NATURAL CEMENT. ADHESION TO BRICK WHEN STORED IN DRY AIR.

Reference.	Kind of brick.	Cement.		Lime paste.						Point aux Pins sand.		Water added (cubic centimeters).	Date made (March, 1895).	Age.	Adhesive strength.				Stored.	Means from column o.		Cohesion briquettes 3 months.		Ratio, column w to column o.
		Kind.	Grams.	Date slacked (March, 1895).	Grams.	Lime contained (grams.)	Water contained (grams).	Lime paste as per cent of total cement and lime paste.	Lime in paste as per cent of lime + cement.	Grams.	Parts to 1 of cement + lime paste.				Mean.	Highest.	Lowest.	Number averaged.		Reference numbers of results averaged.	Mean.	Number tests.	Pounds per square inch.	
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*	*r*	*s*	*t*	*u*	*v*	*w*	*x*
														Months.	*Lbs.*	*Lbs.*	*Lbs.*							
1	Sand molded	X, 41s	120	......	0	0	0	0	0	480	4	100	27	4	17.6	18.6	16.6	2	Dry air	1	17.6	[a] 5	97	5.5
2	....do	X, 41s	120	21	40	14	26	25	10	480	3	84	27	4	29.2	29.9	28.5	2	....do	2 and 7	26.6	[a] 5	99	3.4
3	....do	X, 41s	90	21	30	10	20	25	10	480	4	76	27	4	20	25	15	2	....do	3 and 8	20.2	[a] 5	101	5.5
4	....do	X, 41s	60	21	60	20	40	50	25	480	4	60	27	4	21.7	24.2	19.1	2	....do	4 and 9	20.4	[a, b] 4	40	2.1
5	....do	X, 41s	0	21	120	41	79	100	100	480	4	14	27	4	12.7	13.1	12.3	2	....do	5 and 10	11.8	[a] 5	59	4.6
6	....do	X, 41s	120	21	0	0	0	0	0	480	4	100	27	......	......	......	......	......	......	......	......	......	......	......
7	....do	X, 41s	120	21	40	14	26	25	10	480	3	84	27	6	24.1	25	23.8	2	Dry air	......	......	([a, b])	......	......
8	....do	X, 41s	90	21	30	10	20	25	10	480	4	76	27	6	20.4	24.8	16	2	....do	......	......	([a])	......	......
9	....do	X, 41s	60	21	60	20	40	50	25	480	4	60	27	6	19.2	23.5	15	2	....do	......	......	([a])	......	......
10	....do	X, 41s	0	21	120	41	79	100	100	480	4	14	27	6	11	13.9	8	2	....do	......	......	([a])	......	......
11	....do	Gn. LL	120	21	0	0	0	0	0	480	4	110	27	4	39.5	40	39	2	....do	11 and 16	32.5	[a, b] 2	18	.5
12	....do	Gn. LL	120	21	40	14	26	25	10	480	3	94	27	4	32.5	38	27	2	....do	12 and 17	31.7	[b] 5	38	1.2
13	....do	Gn. LL	90	21	30	10	20	25	10	480	4	84	27	4	36.1	48	24.2	2	....do	13 and 18	30.7	[a, c] 3	21	.6
14	....do	Gn. LL	60	21	60	20	40	50	25	480	4	66	27	4	27.9	30.5	25.4	2	....do	14 and 19	27.6	[b, c] 4	22	.7
15	....do	Gn. LL	0	21	120	41	79	100	100	480	4	14	27	4	11.4	11.4	11.4	2	....do	15	11.4	[a, b] 5	68	6
16	....do	Gn. LL	120	21	0	0	0	0	0	480	4	110	27	6	25.6	26.4	24.9	2	....do	......	......	([a])	......	......
17	....do	Gn. LL	120	21	40	14	26	25	10	480	3	94	27	6	31	32.9	29	2	....do	......	......	([d, e])	......	......
18	....do	Gn. LL	90	21	30	10	20	25	10	480	4	84	27	6	25.4	29.7	21.1	2	....do	......	......	([b])	......	......
19	....do	Gn. LL	60	21	60	20	40	50	25	480	4	66	27	6	27.4	30	24.8	2	....do	......	......	([a, b])	......	......
20	....do	Gn. LL	0	21	120	41	79	100	100	480	4	14	27	6	......	......	......	......	......	......	......	......	......	......

Series 73.—Adhesion of mortars.—Lime with cement.—This series gives the results of a large number of tests on the adhesive strength of cement mortar to brick, and the effect on the adhesive and cohesive strength of mortars, of mixing lime paste with cement. Table 1 gives the results of tensile tests of the mortar, while Table 7 gives the results in adhesion. The briquettes reported in Table 1 were allowed to harden in dry air. The results indicate that 10 per cent of lime paste has little effect on the tensile strength of the Portland cement mortar, while 25 per cent or more is injurious. The brand of natural cement used in this table does not harden well in dry air and the highest tensile strength is given by the lime paste without cement. The adhesive tests corresponding to the results in this table are given in Table 7.

SERIES 76.—*Use of limestone screenings as sand; varying fineness.*

Reference.	Cement, brand R, sample J.	Sand. Fineness (per cent of each size grains). C.	M.	F.	V.	Grams.	Void 5 per ct. theoretic by weight.	Parts to 1 cement.	Water.	Water (per cent dry ingredients).	Solid cement and sand.
a	b	c	d	e	f	g	h	i	j	k	l
	Grams.								c. c.		c. c.
1	200	0	100	0	0	600	46	3	130	16.2	289
2	200	40	30	20	10	600	35.1	3	130	16.2	289
3	200	25	25	25	25	600	30.6	3	136	17	289
4	200	30	25	15	30	600	28.3	3	136	17	289
5	200	50	0	0	50	600	25.4	3	130	16.2	289
6	125	0	100	0	0	625	46	5	110	14.5	274
7	125	40	30	20	10	625	35.1	5	110	14.5	274
8	125	25	25	25	25	625	30.6	5	114	15.2	274
9	125	30	25	15	10	625	28.3	5	110	14.5	274
10	125	50	0	0	50	625	25.4	5	114	15.2	274

Reference.	Volume mortar.	Date made (December, 1894).	Age.	Tensile strength. Mean.	Highest.	Lowest.	Number averaged.	Molder.	Time in mold.	Where stored.	Weight of 10 briquettes just before breaking.
	m	n	o	p	q	r	s	t	u	v	w
	c. c.		Mos.	Lbs.	Lbs.	Lbs.			Hrs.		Grams.
1	420	18	6	509	552	452	10	M.	11	Tank C.	1,465
2	425	18	6	505	574	457	10	M.	11½	Tank C.	1,466
3	425	18	6	470	510	423	10	M.	11½	Tank C.	1,445
4	420	18	6	496	539	463	10	M.	12½	Tank C.	1,448
5	....	18	6	487	531	453	10	M.	10	Tank C.	1,455
6	400	19	6	324	397	286	10	M.	13	Tank C.	1,438
7	395	19	6	392	425	364	10	M.	12½	Tank C.	1,480
8	397	19	6	356	386	315	10	M.	10	Tauk C.	1,455
9	390	19	6	391	411	336	10	M.	14	Tauk C.	1,470
10	395	19	6	349	377	293	10	M.	7	Tauk C.	1,460

C passes 10 sieve (holes 0.08 inch square); retained on 20 (0.033 inch square).
M passes 20 sieve; is retained on 30 (holes 0.022 inch square).
F passes 30 sieve; is retained on 40 (holes 0.017 inch square).
V passes 40 sieve (holes 0.017 inch square).

Series 76.—Varying the fineness of limestone screenings used as sand.—It appears that in a 1 to 3 mortar the highest strength is obtained when the grains are all of about the same size, but that when poorer mortars are in question the result is affected by the proportion of voids in the sand.

UNUSUAL CORROSION OF MARINE MACHINERY.

By Mr. Hector Maccoll, of Belfast.

(*Proceedings Institution of Mechanical Engineers (London) No. 3, July, 1896, Page 345.*)

Corrosion in marine engines and boilers is usually confined to well known parts, is not rapid in its action, and may be prevented or stopped by the adoption of suitable measures. In a recent instance its action was so widespread, so rapid, and so powerful as to render a short description of it somewhat interesting to engineers.

Steamer.—The steamer "Glenarn" is a steel vessel of the long raised quarter-deck type, built in Belfast in 1890 for the Antrim Iron Ore Co., and is engaged in their trade between Belfast and ports on the northeast coast of Scotland and England. She is classed 100 A 1 in Lloyd's register with a dead-weight capacity of about 800 tons; and her machinery consists of three-crank triple engines with cylinders 17, 27 and 44 inches diameter by 30 inches stroke, a three-furnace single-ended boiler of the usual type loaded to a pressure of 165 lbs. per square inch, and a single-furnace horizontal multitubular donkey-boiler. The shafting and other forgings are all of iron; the boilers are of steel with iron tubes.

Submergence.—On Tuesday, 24th December, 1895, this steamer, carrying a cargo of about 650 tons of "burnt ore" from Irvine to the Tyne, struck on a rock in the Sound of Mull, and was at once beached in Scallaster bay, where the sea stood a little over her after-deck at low-water, and close up to her bridge-deck at high water. On the following Monday, 30th December, after having been submerged six days, she was pumped out and raised. On the same day steam was got up in the main boiler; but when about 30 lbs. pressure had been reached, the steam valve on the donkey-pump blew out, and it was found that the copper at the bend of the donkey feed-pipe next the main boiler had disappeared; fires were therefore drawn and the boiler blown off. On Friday, 3rd January, 1896, all leaks having been so far reduced as to be under control of the salvage pumps, the vessel left in tow for Belfast where she arrived early on Saturday morning, all the salvage operations having been successfully conducted by Capt. Bachelor, of the Liverpool Salvage Association.

Cause of Corrosion.—On examination the machinery was found to present an extraordinary appearance; all wrought-iron work was

deeply and roughly corroded, and planed cast-iron work rendered so soft as to be easily cut with a knife. These unusual defects were undoubtedly caused by the cargo of "burnt ore;" and the following explanation has been contributed by Mr. S. Courtney, chemist, of Messrs. Francis Ritchie & Sons, Belfast, who investigated the subject at the request of Mr. Robert Browne, secretary and manager of the Antrim Iron Ore Co: "Burnt ore is the residue from the manufacture of vitriol from sulphur pyrites, and is generally found to contain about 4 per cent of sulphate of copper, together with a little sulphate of iron, due to the sulphur not having been completely burnt out of the ore and becoming oxidized into sulphates. The sulphate of copper would be more or less completely dissolved in sea water, and as the latter contains a considerable quantity of chloride of sodium or common salt, this would react on the sulphate of copper, forming sulphate of sodium and chloride of copper. The sulphate of copper and chloride of copper are both soluble in water; and a solution of either, or both, dissolves wrought-iron and cast-iron. The chloride is more energetic in its action than the sulphate; but in time a solution of either, no matter how weak, will dissolve an atom of iron for every atom of copper present. Every hundred tons of cargo contained as much sulphate of copper as would, if available, dissolve nearly 32 cwts. of metallic iron. The burnt ore might also contain a small quantity of free sulphuric acid, which would combine with the soda of common salt in the sea water, and set free hydrochloric acid, and the latter would rapidly act upon copper or brass."

Extent of Corrosion.—On the condition of affairs being discovered, the engines and boilers, as well as the hull, were at once opened up for survey, the underwriters being represented by Mr. Henry H. West, of Liverpool, and the owners by Mr. James Maxton, of Belfast; the entire work on the hull and machinery was afterwards carried out under the direction of the latter. The general conditions of the engines was that wrought-iron work had been penetrated by corrosion to a depth of about 3-32nds inch, and planed cast-iron so softened that ⅛th inch had to be taken off before a hard surface was regained. Surfaces in bearing contact, or with oil between them, and all painted surfaces, were completely preserved.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—7TH OF JULY, 1897.

A regular meeting (the 367th) of the Society was held in its rooms at 8 o'clock, Wednesday evening, the 7th of July, 1897, President Thomas T. Johnston in the chair.

The minutes of the previous meeting were read and approved.

The Secretary reported for the Board of Direction as follows: "At a meeting of the board held the 22d of June, the Membership Committee presented for favorable consideration the applications for admission of Edward S. Jenison and Geo. C. Waterman and a poll of the members of the board present was had, all voting in the affirmative. The resignations of Messrs. Andrew Onderdonk and John A. Cole were accepted. Application for admission as junior from John E. Grady was received, read, placed on file and referred to the Membership Committee. Mr. B. B. Carter was appointed an auxiliary member of the Library Committee. At a board meeting held the 6th of July, 1897, Messrs. Edward S. Jenison and Geo. C. Waterman, having received affirmative vote of the whole board, were declared elected as members.

The committee appointed to examine the condition of the iron work on the old post-office and custom house of Chicago rendered its report, which was read and ordered filed. The subject was open for discussion and Mr. Emil Gerber commented upon it at considerable length.

The paper of the evening, "Limestone Screenings in Cement Mortar," a series of tests prepared under the direction of Professor A. N. Talbot, of Illinois University, was read by the Secretary. Mr. Alfred Noble discussed the subject in a written paper, which was followed by remarks from Messrs. W. J. Yoder, H. P. Boardman, J. W. Dickinson, Mr. Keolling and the chair.

Samples of screenings and material were on the table for inspection.

The Entertainment Committee made progress report regarding a proposed excursion to Niagara Falls and Toronto. Adjourned.

A meeting (the 368th) of the Society was held in its rooms at 8 o'clock, Wednesday evening, 21st of July, 1897, President Thomas T. Johnston in the chair (forty members and guests present).

The minutes of the previous meeting were read and approved.

The Secretary, in reporting for the Board of Direction meeting of 20th of July, announced the election of John E. Grady as junior and the receipt of applications for membership from Hiram J. Slifer and John Williamson, which were received, read and referred to the Membership Committee.

The Entertainment Committee made additional report of progress on the contemplated excursion. The matter, after discussion, was referred back to the committee to make such arrangements as seemed best.

Mr. F. G. Gasche was introduced by the chair and proceeded to read his paper on "Causes of the Variable Efficiency of Steam Boilers, and Their Influence on Tests." Diagrams to aid in illustrating the subject were then thrown on a screen by the stereopticon. The reading finished, the discussion was opened by Mr. L. L. Summers, and entered into by the author, Messrs. Windett, Royse, Monroe, Winger and the chair. Adjourned.

A regular meeting (the 369th) of the Society was held in its rooms on Wednesday evening, 4th of August 1897, President Thomas T. Johnston in the chair. The minutes of the previous meeting were read and approved.

The Secretary reported for the Board of Direction at its meeting, 3d of August, '97; applications for admission of Arthur J. Cox and R. Y. Maxon were received, read placed on file and referred to the Membership Committee.

The Entertainment Committee stated that a better rate could be secured by postponing the excursion to Niagara Falls until about 23d of September, at the time of the ceremonies of the Grand Trunk Ry. Co. over their new arched

bridge. A discussion of the matter followed, and the report and advice of the committee accepted. Due notice of the excursion to be sent to all members.

As there was no further business the chair announced the paper of the evening, "The Internal Hydrostatic Pressure in Masonry, with Especial Reference to Masonry Dams," prepared by Messrs. Broenniman and Ross, and introduced Mr. Arnold Emil Broenniman, who stated that owing to the length of the paper he would abridge it in his reading.

At the conclusion of the reading Messrs. Bainbridge, Beardsley, Curtis, Bley and the chair entered into a discussion of the subject.

The chair then stated that the subject to come before the society at the next meeting would be *moto-cycles*, and that a committee on papers representing the *electrical* element of the society have had the matter in hand for some time, and have collected some very interesting data on the subject. Communications on the matter from manufacturers at home and abroad have been received, and it is hoped considerable discussion will be brought out.

Mr. Bley moved a vote of thanks to the authors of the paper just read, which was seconded and unanimously carried.

Adjourned.

NELSON L. LITTEN, *Secretary.*

24th of August, 1897.

LIBRARY NOTES.

The Library Committee wish to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid in completing valuable volumes for our files.

Since the last issue of the Journal, we have received the following as gifts from the donors named:

Am. Inst. Mining Engrs.—Vol. XXVI.
Index Vols. XXI to XXV.
Ass'n Civil Engineers Cornell University—Transactions of, Vol. V, 1896-7.
McCormick Harvesting Mach. Co.—Who Invented the Reaper?
The Ry. Equipment & Pub. Co.—Pocket List of R. R. Officials, 3d qr. '97.
The Ry. List Co.—The Official Ry. List, 1897.
S. S. Greeley—Internat'l System of Metric Weights and Measures.
Levels of the Lakes as Affected by the Proposed Lake and Gulf Waterway, a discussion before the W. S. E.
Landscape Architecture, H. W. S., Cleveland, 1873.
Opening Ceremonies of the N. Y. and Brooklyn Bridge, May 24, 1883.
19th Annual Report of Department of Public Works, Chicago, 1894.
Report for 1896 of Methods and Results, Secular Variation of the Magnetic Declination in the U. S.
History of the Chicago Police, 1887.
Papers Read before the Engineering Ass'n of the South, April, '96.
Proceedings Ass'n Ontario Land Surveyors, 1896.
Proceedings Iowa C. E. & Surveyors' Society, 1895.
Proceedings Iowa C. E. & Surveyors' Society, 1896.
Proceedings Conn. C. E. & Surveyors' Ass'n, 1896.
Proceedings Indiana Engineering Society, 1894-5.
Proceedings Indiana Engineering Society, 1896.
Transactions Ohio Soc'y of Surveyors and C. E., 1895.
Transactions Ohio Soc'y of Surveyors and C. E., 1896.
Report 1st Annual Meeting Ill. Soc'y of Engineers and Surveyors, 1886.
Report 4th Annual Meeting Ill. Soc'y of Engineers and Surveyors, 1889.
Report 6th Annual Meeting Ill. Soc'y of Engineers and Surveyors, 1891.
Report 7th Annual Meeting Ill. Soc'y of Engineers and Surveyors, 1892.
Report 8th Annual Meeting Ill. Soc'y of Engineers and Surveyors, 1893.
Report 9th Annual Meeting Ill. Soc'y of Engineers and Surveyors, 1894.
Report on an Additional Water Supply for Rockford, Ill., 1891.
The True Exterior Boundary of Townships, Z. A. Enos.
The Legal Length of Subdivisional Lines in Interior Sections.
Illinois State Building World's Columbian Exposition, 1893.
The Waterway between Lake Michigan and the Mississippi River.
The Nicaragua Canal.
Street Carriageway Pavements.
Wood as a Paving Material under Heavy Traffic.
Discussion on above.

The library and reading rooms are open from 9 A. M. to 5 P. M., on week days, except Saturday, until noon.

Journal of the Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

VOL. II. OCTOBER, 1897. No. 5

XV.

MOTOCYCLES.

Read September 8th, 1897.

INTRODUCTORY.

For the purpose of developing a discussion on Motocycles, in the furtherance of a more general interest and wider dissemination of information on the subject, which would be conducive to the earlier utility of this mode of transportation for commercial uses, and pleasure as well, the Electrical Committee of the Western Society of Engineers, consisting of Messrs. H. M. Brinckerhoff, L. L. Summers and Bion J. Arnold, formulated a circular outlining the following general divisions of the subject for consideration:

1. Preference as to driving power with reason as to selection. 2. Economy. 3. Control. 4. Convenience. 5. Design and construction. 6. Safety and reliability. 7. Field of application. 8. Limiting conditions. This was mailed to members of the Society and others, both at home and abroad, especially interested in the various forms of horseless vehicles, with results as disclosed in the following pages:

SOCIETE DES INGENIEURS
CIVILS DE FRANCE.

PARIS, May 10, 1897.

MR. NELSON L. LITTEN, Secretary Western Society of Engineers:

I have the honor to acknowledge the receipt of your letter dated April 23, inclosing the questions with regard to a "Discussion on Motocycles."

I have referred your note to some of our members who are more especially interested in this subject, and they have promised to reply at once. Yours truly, A. de DAX,
Secretaire Administratif de la Societe des Ingenieurs Civils de France.

R. VARENNES,
INGENIEUR CIVIL,
10 AVENUE FLACHAL.

ARNIERES (near Paris), May 19, '97.

MR. NELSON L. LITTEN, Secretary Western Society of Engineers:

M. de Dax, general secretary of the Society of Civil Engineers of France, has asked me to reply to the questions about automotors sent him by you.

1st. Preference as to driving power with reason as to selection.

The advantages of the automotor are:

1st. Greater security than with horses, greater rapidity, saving in employes or servants. No expenses when not in use.

2d. Economy.

The economy in the use of automotors over horses in France is not questioned.

3d. Control.

In France we are of opinion that the driver has to attend to the steering and the machine. It is better not to have the responsibility resting on more than one person.

4th. Convenience.

In France the automotors for pleasure traveling are all provided with motors which use petroleum of a density of 700 grammes per litre. All automotor carriages can make at least 100 kilometers (60 miles) without refilling. Petroleum can be bought every twenty-five to thirty miles, so refilling is assured. The best automotors are those manufactured by Panhard & Levassor, 19 Avenue d'Ivry, Paris. It is the best French make and superior to others. The odor is hardly observable, and does not incommode the travelers. The noise of the motor is hardly heard; it is less than that made by the shoe of a horse on the pavement. The petroleum carriages are very simple; the owner, as a rule, can manage it himself, and there is no need for taking a machinist along on the trip.

These carriages, seating 2 to 4 persons with motor of 4 to 5 horse-power, weigh about 1,500 lbs.

Seating 4 to 5 persons with motor of 6 to 7 horse-power, 2,000 lbs.

Seating 5 to 8 persons with motor of 8 to 10 horse-power, 2,600 to 2,800 lbs.

This weight does not include occupants, only the carriage ready for the trip.

The steam carriages are generally dearer and not used when great speed is required. They are used as public carriages or for the transportation of merchandise. They are not favored by the public as much as the petroleum carriages.

There are actually about 1,200 automotors in France used for pleasure trips. Among them are not more than twenty-five steam carriages.

The automotors for passenger traffic are only in use between Paris and Colombes-Seine They are the steam automotors of

the Scotte system. The service commenced a month ago and is satisfactory.

5th. Design and Construction.

Frames built of round bicycle tubes are not strong enough. We prefer U shaped iron or any other. Sometimes wood and iron is used. Wheels, except for light carriages, don't seem to give as much satisfaction as the ordinary wooden wheels furnished with rubber tires.

The means of transmission are numerous.

The chain is most used.

The revolving axle has been abandoned by good constructors.

Every wheel turns on a fixed axle.

An intermediate shaft carries the differential.

6th. Safety and Reliability.

There is no danger of explosion when the hydro-carbon gas motors are used.

Some precautions are indispensable against fire. Accidents due to fire have been so rare in France that they can be practically neglected. Such is the opinion of the fire insurance companies.

There is no need of experienced help. The owner runs the petroleum carriage himself, and after eight days handles it better than a professional mechanic. This seems paradoxical, but is true.

7th. Limiting Conditions.

In France the authorized maximum speed in the town is 15 kilometers (9.5 miles) and outside the town 30 kilometers (19 miles) per hour.

When the automotor carriages weigh more than 2,000 kilograms, including the passengers, the speed is decreased to 13½ kilometers (8½ miles) and 24 kilometers (15 miles) per hour.

The above rate of speed refers to the traveling automotors.

Delivery wagons do not make more than 10 to 12 kilometers (6½ to 7½ miles) per hour.

In France the roads are generally very good, except in the neighborhood of Paris. In rainy weather the speed of 30 kilometers (19 miles) is sure to be reduced to about 22 kilometers (13¾ miles).

Personal Experience.

I have made 3,780 kilometers (2,360 miles) with a Tanhard & Levassar automotor. I did not meet with the slightest incident or accident.

Last summer I traveled 5,200 kilometers (3,250 miles) in three months. I had only one incident on the road, a stop of twenty minutes for repairs Yours respectfully,

RENE VARENNES, C. E.

Ingenieur Civil, Membre des Comite de l'Automobile Club de France.

FELIX MILLET,
INGENIEUR CONSTRUCTEUR.

PERSAN, FRANCE, May 31, '97.

MR. N. L. LITTEN, Secretary.

Dear Sir: In reply to your letter of the 7th to Society of Civil Engineers of France, I send you by post twelve blue prints. Some represent an automotor bicycle run by a motor of my invention, and the other prints represent suggestions of some automotor carriages with the same motor. This motor is rotary, has cylinders and pistons but no dead center. All the parts have a continuous motion, giving no shocks so pronounced in reciprocating motions and no vibrations.

FIG. 201. Felix Millet Bicycle.

The bicycle shown weighs 60 kilogrammes (132 lbs.), but can be made much lighter. Its motor is of one horse-power and the speed of 300 revolutions per minute, and gives the bicycle a speed of 60 kilometers (37 miles) per hour on a level road with a consumption of one litre of mineral oil for every 50 kilometers run (120 miles per gallon oil).

The ignition is by an electric spark. The cooling of the cylinders takes place by the circulation of the air. You can find a complete description in the patent office records for 1895.

I am anxious to sell my rights to an American company.

This rotary motor can be used with gas, steam and water or compressed air after some modifications have been made.

Yours truly, FELIX MILLET.

Catalogue price lists and book of directions for care and operation of their automotors were received from Panhard & Levassor, 19, Avenue d'Ivry, Paris.

Price list shows cost to vary from $900 to $1,300 for vehicles seating from two to eight persons.

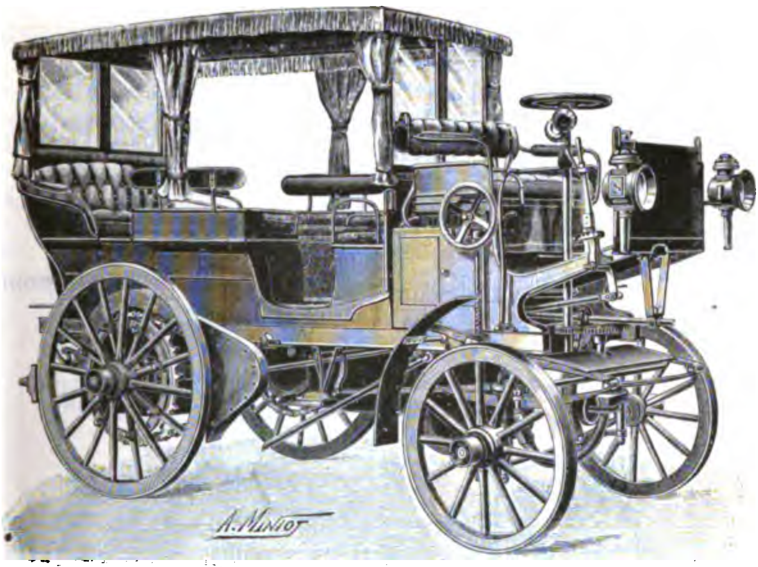


FIG. 202. Grand Break. (Panhard & Levassor.)

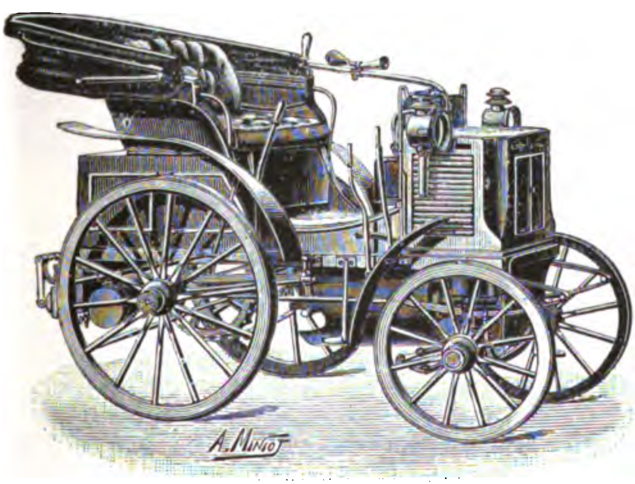


FIG. 203. Two-Seated Vehicle with Top. (Panhard & Levassor.)

SOCIETE ANONYME
DES
AUTOMOBILES PEUGEOT.

AUDINCOURT, FRANCE, May 8, 1897.

Monsieur le Secretaire de la Societe des Ingenieurs de l'Ouest, 1737 Monadnock Block, Chicago:

In reply to your favor dated April 23, we send you the following:

1st. The Revue Velocipedique containing an article on the Peugeot motor.
2d. Our rate of prices.
3d. Five autographes representing our carriages provided with the new Peugeot horizontal motors.
4th. Instructions for the use of our carriages.

This is all we are able to send you concerning our automotors.

Yours truly,

D. RIGOULET.

President and Director, Societe Anonyme des Automobile Peugeot.

DESCRIPTION OF THE NEW HORIZONTAL PEUGEOT MOTOR.

(From L'Industrie Velocipedique and Automobile.)

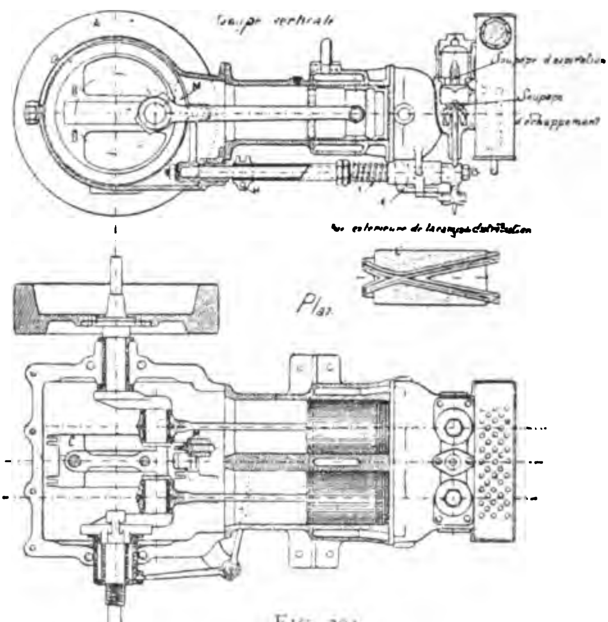


FIG. 204.

A—Cover. C—Distributing Cam. H—Socket. I—Spring. M—Guide.

The well known Peugeot carriages were propelled by the Daimler motor with two cylinders placed at 15° with the vertical, until the Marseilles-Nice race. The carriage engaged in the race was provided with the new horizontal motor. It arrived first of the petroleum carriages. The steam break from Dion was a few minutes ahead. The test places the Peugeot motor in the first rank.

The two cylinders are placed horizontal and parallel. In front are the cranks and the main shaft, behind compression chambers and valves; behind the chamber are two lighting tubes heated by a burner surrounded by a metallic covering.

The center shaft and the crank have a metal cover which serves to carry the main shaft and protects the machinery against dust and dirt. The shaft is provided with a fly-wheel which transmits the motion of the motor to the different shafts by means of a belt. A ball governor and a distribution cam are connected with the shaft.

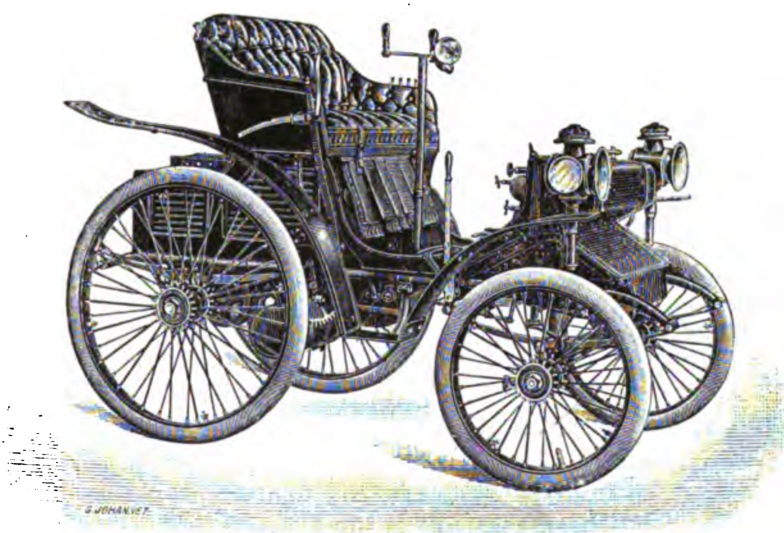


FIG. 205.

The shaft extends beyond the case opposite the fly-wheel so as to receive a handle for use on the road.

The cylinders are cooled by the use of a cover allowing water to circulate, keeping the cylinder at a proper temperature.

For the purpose of cleaning or examining the valves it is sufficient to unscrew the nut in the upper part of each case. The cover over the governor, etc., is as easily removed.

The really new feature of the Peugeot motor is its system of distribution.

A guide M at the end of a lever mounted on the distribution

shaft receives an angular motion by means of a groove of the cam in which it is working.

This groove makes two turns before repassing the same point. The piece in V reversed lifts the escape valve at every other revolution.

The motor running quarter stroke receives an impulse at every turn. The explosion is produced successively in each cylinder. If the speed of the motor increases too much the centrifugal governor overcomes the resistance of the spring I and aided by a system of levers, removes the stem of the escape valve in such a way that the burning gas cannot escape, and an explosion is prevented. The speed of the motor diminishes, and after it has become normal the spring I works again and permits the escape cam to act on the valve, and the burning gas exhausts.

W. WORBY BEAUMONT,
M. INST. C. E.
M. INST. MECH. E.

OUTER TEMPLE, 222, STRAND, LONDON, W. C.
(Opposite the Royal Courts of Justice.)
July 7, 1897.

NELSON L. LITTEN, Esq., Western Society of Engineers,
1737 Monadnock Block, Chicago.

Dear Sir: Being exceptionally busy at the time of the receipt of your letter 26th April last, I was unable to take advantage of the invitation you kindly sent me to take part in your discussion on Motor Cycles.

Under another cover I send copy of one of my papers on the subject and will be pleased to send the Cantor Lectures referred to if of any interest to your society.

I am, faithfully yours,
W. WORBY BEAUMONT.

The following is an extract from the paper to which Mr. Beaumont refers:

MOTOR VEHICLES FOR ROADS.*

So much has been said and written concerning mechanical road-vehicles, their motors and gear, that I cannot avoid some repetition in dealing with the subject again, especially as there is not yet much to be said concerning the recent and pending advances. * * * * *

With the steam-engine we have greater range and ease of manipulation, within the limits of no power and full power, than with any other motor; for short periods it may be made to give more than its proper maximum, it may be stopped and started with more freedom, certainty, and smoothness than any other motor, with the exception of the electrical; it may be employed

*From two papers, one read on the 27th of March, before the Manchester Association of Engineers, and one on the 29th of March, before the Cleveland Institute of Engineers, (England).

for traveling any distances with fuel available everywhere, is easily fitted with reversing gear, and is easily understood.

Now, for long-distance work the only competitor at present with this is the oil or the spirit motor, the disadvantages of which are small range of power within the maximum, no excess of power for short periods, difficulty of starting, and consequent necessity for keeping the engine running when the carriage is stopped for short periods; vibration due to explosive impulse on the piston, and necessity for running the motor at nearly full speed before starting the vehicle, most of the change of speed having to be made by frictional or other gearing. The motor and vehicle cannot be started together, and hence, whenever the vehicle is started the motor is called upon to attempt to impart to it a speed equal to that proper to the lowest ratio of the speed gear. A frictional gear means loss of power and loss of time in overcoming the inertia of the vehicle, and unless the frictional clutch is connected to the motor through very low speed positive gear, the starting is almost certain to be effected more or less jerkily. * * * * *

Having described the disadvantages of the oil or spirit motor, it is necessary to describe their merits as compared with the steam-engine. The first is that the oil-engine requires no steam generator and no condenser. It uses fuel of a high calorific value, easily carried, and no trouble to apply, and it uses it more economically than the same fuel, oil, can be used for the generation of steam. As it needs no apparatus for the generation of the working fluid, there is no such apparatus to attend to and no space required by it. Hence the motor and gear can be much more conveniently arranged than the steam-engine. This it is that gives it all its advantages over the steam-engine, even assuming all the little troubles connected with boilers and condensers to be entirely overcome. The motor will, however, weigh a little more than the steam-motor of equal power, running at equal speed, and this may, perhaps, be put at 25 per cent. The weight, moreover, of a boiler and condenser is not all in excess of the oil-motor, for jacket water arrangements and exhaust silencer have to be included. The oil-motor cannot, however, use the cheapest fuel, such as coal or coke, or even crude or the partly-refined petroleums, and this is an objection to it for the larger powers and for vans and vehicles, which must in any case have a paid driver and attendant to whom the work of stoking would be part of his duty. It is, moreover, an objection to oil-engines for such purposes that they in some respects depend upon more delicate adjustment as to air, vapor, and oil supply, admission and ignition, and it is not always that even those well acquainted with oil-engines can say precisely and at once why an oil-motor will not start, or being started will not continue to work. The cause may be one of a dozen things which are not obvious, and which may take a good many minutes to find out. In a correspond-

ing sense, the steam-engine is not at all delicate, and this is an advantage it will probably offer for a considerable time, but with decreasing force as the motors become more definite or fixed in points which are now subject to adjustment and are more generally understood. In the oil-motor, either the main or the supplementary air supplies may be too much or too little, the oil supply may be too much or too little or may stop, the exhaust or the air valve may either of them leak or be made temporarily to leak, by dirt under the seat or part of it, or by corrosion or erosion, and in any of these cases it is difficult to say what is happening. The ignition tube may not be hot enough; this may be seen, or it may be stopped or partly so, which cannot be seen, and this must be guessed, or, like any of the other numerous things, must be diagnosed. To sum the matter up, it may be said that the steam-engine would be in every way the best were it not for its boiler and condenser or escaping steam; and that the oil-motor is best where the boiler and condenser are both inadmissible, and where the vibration it causes and its occasional freaks (which are diminishing in frequency) are not sufficient reasons for rejecting the advantages of motor-carriages.

We are thus led to the conclusion that steam propulsion is mainly a question of steam generator, for, although a condenser is very desirable, the passage of the exhaust steam into the uptake, as was done by Gurney, Hancock, Holt, and Mackenzie, might be considered sufficient means of disposal for many kinds of vehicles. A condenser is not, however, an impossibility, and a combination of the air and evaporative condenser systems will probably lead to the solution of the problem. The construction of a suitable very light generator is not, however, very easy, and it would seem that, in spite of the high efficiency of a boiler made upon Hancock's system, with numerous flat thin chambers, with thin passages between them for the heated gases, the weight of the enclosing plates and buck-stays cannot be brought below a minimum which is too great. Other methods of supporting the pressure of the sides of the envelopes might be devised, but increase in the number of joints is undesirable. A generator of the instantaneous kind, although those of Serpollet are heavy, seems to offer itself as the best means at present available. The objection as to want of heat storage is one which would have to be overcome by means of a furnace or other heat supply which can be made to respond rapidly to a call for a maximum quantity of steam for some little time. Heat accumulation in the form of heated water cannot be obtained with this class of generator, and the specific heat of iron being very low, storage by thick or cast-iron coated tubes is a very inefficient addition to weight. The generator question, therefore, resolves itself into one of the construction of a suitable rapidly responsive furnace for ordinary fuel, or of burners for liquid fuel, acting in concert with the steam demand from an instantaneous generator, or one in which the

weight of the water-containing space is not materially greater than that of a mere tank for carrying the same quantity of water. With a good condenser even this qualification need not be conceded; but, ignoring the value of pure water, the economic question is one of selection as between (1) the boiler containing a quantity of water, accompanied by a water-tank; (2) the lighter, instantaneous generator with no water contents, and demanding no care as to water level by a larger watertank; or (3) an instantaneous generator and a condenser and a water-tank of merely nominal capacity. The weight of the condenser seems to be the determining quantity for this. Such generators as that used by H. S. Maxim for his flying machine suggest another line of development. This boiler contained a very large number of thin ⅜ copper tubes connected to larger trunk tubes, none of them containing much water, and a steam receiver of small diameter. Most of the tubes were only 1-50 inch thick, and with four of these in a white-hot furnace Maxim found he could evaporate 26½ lbs. of water per hour per square foot of surface. His boiler was heated by gasified naphtha, and contained 800 feet of heating surface, and weighed 1,000 lbs. with feed heater. Inventions and patents for light steam generators are numerous enough, but none are yet, or not more than one or two are being used, even experimentally.

Most of the makers who use gear transmission between the engine and second motion shaft employ the three or four speeds, but those who use belts avail themselves of the slip of the belts more or less controlled to vary speed between the two which are mostly used. Belts are not, however, to be commended for vehicles, because the belts must be short, some must be crossed, and all of them may often have to run in bad, wet weather. For light work the shortness of the belts when on pulleys of no great difference in size may not make great tightness necessary, but for variable work the objections to tightness can only be escaped by using jockey pulleys. In some cases where these are used the belt which for the time being is doing no work is nevertheless running idle on one of the pulleys, or loose on both, and this is objectionable. The use of belts as friction brakes, or in place of better variable speed arrangements, is also objectionable, even if for no other reason than that it polishes the pulleys and makes greater tightness, necessary for a given amount of frictional adhesion. We can only say of it that it is not a bad makeshift.

In Great Britain there are now numerous manufacturers who are making or preparing to make oil or spirit motor vehicles, but for the next two or three months it does not seem that we shall see their vehicles on the road. Some of these makers use the Daimler motor, the construction of the main features of which is so well known as to need no description here. Mineral spirit is used for its operation.

Several makers will use what is known as the Pennington

motor, which is a small light high-speed mineral-spirit motor, the cylinders of which are made of thin steel tubes, as used by Mr. Hiram S. Maxim in his steam-engines for his aerial machine, and from which Maxim got over 360 horse-power from engines which he could support on his lap, weighing 640 lbs., or less than 1.8 lbs. per horse-power actual. The pressure used was 325 lbs. Mr. Maxim is now at work, not only on a gas-engine which will run fast or slow like a steam-engine, and reverse, but on a light steam-engine and boiler or generator of high capacity, a 12-horse-power generator being only 9 inches thick, and in the shape of a book.

I have said nothing as to the smell of the oil or spirit motor—firstly, because it is not or need not be really serious; it is only a different stink from that of those to which we are accustomed, either with horses or steam-engines, and will be lessened by experience.

With regard to the vibration caused by them, I think there is little doubt that this will soon be overcome. The piston and connecting rod of an oil-motor and cylinder are like a shot in a gun, action and reaction being only equalized by different amounts of imparted motion or of inertia of different masses overcome at different velocities. A vertical motor operated by explosions at irregular intervals, and mounted on a springy base is not likely to stand very steady, and as few motors are properly balanced the occasional explosion merely aggravates a vibratory movement of smaller range set up by the continuous rotation of unbalanced parts. The difficulty is one which should be surmountable, but there is no doubt it is less a difficulty with the horizontal engine, and for obvious reasons.

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There appears to be a general opinion in England that the use of mineral spirit is likely to be attended with more risk of accidental ignition and explosion than ordinary lamp petroleum. There is no doubt that more care is necessary, but very little more. Very few accidents have happened with motor-carriages as a result of the use of the mineral spirit, while lamp accidents with ordinary lamp oils happen every day, and often with fatal results. The extra care required in handling mineral spirit is, however, attended with much greater simplicity in the construction of a motor worked by it, and some minutes less time are required in starting than when the heavier oil is used. Hence the fact that all the Continental and American so-called oil-motors use mineral spirit. In contrast with the well-made, economical English oil-engine, with good governing arrangements, any tin toy maker could make a spirit motor which would work, though a great deal of ability and ingenuity have been expended in producing a really useful spirit motor for carriage work. There is still much remaining to be done, not only with reference to complete combustion under the varying loads, and more or less fre-

quent stoppages of motor-car work, but particularly in the construction of an oil or spirit-motor, which in daily ordinary use will work well throughout a considerable range of power, from light load to its maximum. There is also a great field for the inventor of a satisfactory self-starting oil or spirit motor. We seem to be some distance from it at present, but it is not impossible that the combination of a self-starter and existing engine might produce a motor which would start by turning on the oil or vapor supply and igniter, and thus avoid the necessity for keeping the motor running while the carriage stands during short stops.

Concerning electrically-propelled vehicles, there is still not much that can be said with respect to those intended for more than the short runs in towns. The electrical motor possesses all the attributes of a perfect motor for any power within its maximum when used with suitable speed-gear to get over the difficulty of starting the vehicle and climbing steep hills. The one practical difficulty is the great weight of the accumulators required for a few horse-power for a few hours. At present there is no good battery which weighs less than about 500 lbs. per horse-power hour, and this weight far exceeds that of the whole motor machinery required for an oil or spirit motor-car.

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From Sir David Salomons,
49 Grosvenor Street, London, W.

To the Secretary,
May 6, '97.

Dear Sir: As I am suffering from overstrain of work and forbidden to undertake anything beyond fulfilling engagements already made; it is not in my power to meet your request. Indirectly I can do it by referring you to a paper I am to read at the Society of Arts (London) on Wednesday next, May 12. The society publishes the paper, so you will have no difficulty to obtain it.

Yours faithfully,

David Salomons.

The following selections have been made from the paper on "Motor Traffic" by Sir David Salomons referred to in his letter as bearing upon points not covered by other communications.

MOTOR TRAFFIC.

(*A Paper by Sir David Salomons, Read before the Society of Arts, May 12, 1897.*)

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We all know why, thanks to the careful investigations of the late Mr. Froude and others, the fish moves with such freedom in water, when it is completely immersed, the reason being that the power necessary to divide the water in advance is compensated for by the closing of the water behind the fish, which gives it a push. Its curved outline is so admirably formed that the fish is capable of moving through the fluid in which it lives with virtually nothing more than skin friction to be overcome.

The same might be thought to take place in the case of a carriage rolling along a rough road, *i. e.*, the extra power required to get the wheels over an obstacle should be compensated for by the downward run when descending the other side. To some extent, the theory would hold good for exceedingly rapid motion, but not for speeds permitted on high roads, and for the following reasons:

It is evident that a wheel, in surmounting an obstacle, rises gradually, but it descends through a less distance as a rule, because the obstacle, a stone for instance, has probably been sunk into the ground or broken smaller by the wheel's passage.

But supposing no crushing action takes place, as might well be the case with a very light vehicle, then why should the work be harder to pull it over a rough than a smooth road? The answer is, that in passing over a rough road, the speed being slow, the sum of the pulls necessary to get over the obstructions is far greater than the sum of the accelerating forces on descents, owing to the tendency of the wheel to push into the ground before surmounting the obstacle, and this applies in all cases.

If the obstructions on a highway consisted of a series of symmetrical waves, switchback in form, it is clear that the carriage would run slowly up an incline, and more quickly down. The average power used, supposing these undulations to be on an otherwise good road, would be no greater than had these undulations not existed, although the carriage would have advanced by fits and starts.

In giving these various explanations, I have assumed that the horse is drawing the vehicle, and the line of draft is, therefore, at a point somewhat higher than that of the axles, in other words, inclined backwards to the road, which is a great advantage because the pull tends to lift the wheels over the obstructions.

Supposing, now, we place the horse behind the cart, and make him push it with his chest, what would be the result? The wheels, instead of being assisted in surmounting obstructions by the lifting tendency, would now tend to drive themselves into the ground behind the obstruction, and the horse, which might have advanced with the greatest of ease when placed in front, would have his work cut out to push the cart from his new place.

Here we have the condition imposed upon a self-propelled vehicle. This difference between dragging and pushing is well shown in the case of a railway truck on which porters move passengers' luggage. If the truck, when loaded, meets with an obstruction, the only way to advance easily is to turn round and pull it along.

I should like for a moment to consider the manner in which the power is derived from the horse. Of course, we must all admit that primarily it is muscular action, but most people think that a horse advances solely in consequence of the anchorage obtained on the road by means of its feet, whereas there is an-

other very important action brought into play, which those who watch these animals carefully will easily observe.

It is well known that a heavy horse can drag a greater load than a light horse, and I think, when you consider the special point to which I will refer, the reason is very obvious, although of the two horses in question one need not have greater muscular power than the other. Riders are aware that during a trot, and indeed at all times, the body of the horse rises and falls. The rising of the horse is due to muscular power exercised against gravitation, whereas the fall is due to gravitation alone. Since the horse is advancing during the time, a curve of a wave-shaped form would represent graphically the rise and fall of the horse's body. It, therefore, appears evident that there is during half the period of advance, a time when gravitation materially assists the progress of the vehicle, and the greater the weight of the horse the more it will be in favour of the load being pulled. Consequently, the heavy horse has an advantage over the light one for heavy loads.

It appears to me that this, what I would term undulatory advance is in a large measure equalized by the spasmodic advance, due to the horse's feet pushing against the road, and here is to be found one of the chief reasons why the carriage runs with smoothness.

No motor has ever yet been devised combining these two properties. Gordon and others invented vehicles with feet to imitate the progress of the horse, but the rising and falling of the heavy weight was absent in these devices, and may possibly have been the reason why they proved complete failures. It may readily be imagined how jerky the advance would be without this compensating governor.

A few words respecting pneumatic tyres are not out of place.

An ideal road would be one of a hard elastic surface capable of permitting all inequalities to sink into it without friction, when the wheels meet any obstruction lying upon it. Such a road in practice cannot exist. It is, therefore, necessary to seek a means which will produce the same result. A pneumatic tyre, suitably constructed, will give the equivalent of the ideal road, *i. e.*, the obstructions which the tyre meets will sink into it, and the traveling load will not be raised against gravity. Losses by friction, however, remain the same.

The advantages to be derived from the use of the pneumatic tyre cannot, however, be gained except by encountering many other troubles, of which those who use this class of rim are well aware. They may be summed up as the mechanical defects of the system.

There is a popular notion that by the use of the pneumatic tyre advantages are always gained. This is only true if certain conditions are observed.

It is evident that unless the tyre is inflated to a proper degree, which must be regulated by the load, also that it shall be of sufficient diameter that the stones most generally met with on the road will sink into the tyre—the pneumatic, so to speak, must swallow all the obstructions it meets with in its path—its main virtue would be gone.

Personally, I do not view with the utmost favor the pneumatic tyre, on account of the mechanical disadvantages. Indeed, if the springs of a carriage are sufficiently well made and adjusted, a circumstance rarely to be found, the advantage of the pneumatic is almost absent, and I believe that for motor traffic the steel or solid rubber tyre will prove the favorite in the long run, when sufficient attention is given to carriage springs. The chief function to be fulfilled by the carriage spring is to enable the load to travel on the level whilst the wheels of the under carriage are mounting up and down as they pass over road obstructions. The weigh of the portions which rise and fall are very small, compared with the vehicle and its load.

Although it has been asserted that the draft is greatly diminished by the use of pneumatic tyres, my own experience does not bear this out except in given cases. On bad roads an advantage may be gained, but on good ones, the steel tyre carries the palm. Quite apart from experiments, it is only necessary to watch the pull exerted by a horse on various classes of roads with the same carriage tyred in different manners.

It is found that the rubber of the pneumatic tyre will burn if the load is very heavy. Whether this is due to the successive compressions of the air when meeting obstructions on the road, or whether it is owing to the friction of the air in the tube, due to lag in having to pass through a very restricted opening in a portion of the tube, i. e., that part which is in contact with the road, and to friction generally, it is difficult to say. The fact is there. Messrs. de Dion and Bouton had the greatest trouble on this score with their tractors, and finally decided to fall back on the solid rubber.

It is quite possible to make a pneumatic tyre suitable for very heavy roads, but the thickness and size would be so great that the advantages to be derived would be virtually absent. In the case of cycles and motor vehicles of that type, the pneumatic tyre is an undoubted advantage, for in one case it removes much of the vibration from the feet, which would be conducted to the body, and in the other it might be found difficult to introduce suitable springs on the ground of the weight or of expense.

The pneumatic axle is the true solution to the trouble, when a satisfactory one is made.

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I will now turn to steam power on the highway. After a careful study of probably every self-propelled carriage which has been made from the earliest times to the present day, I have

come to the conclusion that Hancock's disposition of the working parts cannot be improved upon. This was my opinion long ago, and I was pleased to find Sir Frederick Bramwell and others uphold the same view. I pointed this out to M. Serpollet, who, having examined the matter, is in full agreement and his new carriages are being built on these lines. I regard this circumstance as a compliment to English engineering.

Of all motors for carriages at the present day, I hold that steam is by far the most suitable and advantageous for real work, and that when the Serpollet boiler or one of a similar type is employed, nothing more can be desired for many years to come.

Of English manufacturers already busy at work on steam road vehicles, Messrs. Philipson and Thornycroft may be reckoned among the leaders. The steam carriage which has been brought nearest to perfection at the present time is that designed by M. Serpollet. I will therefore give a brief description of his vehicle with its most recent improvements. M. Serpollet has adopted the present type from the instructions I gave for the carriages constructing for me.

The engine and disposition of the parts are all simple matters not subject to patents and not capable of material improvement, as they have all been common knowledge for the past 70 or 80 years. The boiler and furnace alone have been the main difficulties in connection with the subject. Many waterless boilers appeared before M. Serpollet's time, but to him the credit is due for having devised a form of boiler, simple, cheap and effective.

The principle of the Serpollet boiler is so well known that I need not enter into it again. It will only be necessary for me to describe the boiler and furnace in their most recent form. The earlier ones were not practical from an engineer's point of view; the furnace was large, a great weight of fuel was necessary, and fumes were produced.

The present boiler is made up of several tiers of crushed bent tubes, the steam space being horseshoe in section, and a petroleum furnace. The chief improvements consist in very materially strengthening the metal of the tubes, which gives the advantage of a reserve for storing heat, which is essential, as well as for durability's sake, and the method upon which the tubes are built up is far simpler and renders repairs, when found necessary, rapid and easy to carry out. Those tubes which are nearest the fire are thicker than the elements more distant. In some forms the tubes are further bent into spirals, thus giving additional strength and an increased heating surface.

The fire itself being a heavy oil petroleum furnace, offers lightness and security against breakdown and accident. A large reduction in weight, due to this form of furnace, gives an all-round advantage, especially now that the engines are constructed to condense.

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Briefly, the following is a summary of the advantages presented by the new petroleum furnace:

1. No smoke is produced when the burner is preparing to be lit.
2. Very little methylated spirit is required for lighting.
3. When making a stoppage for a considerable time, such for instance as paying a call, the petroleum is cut off from the main burner, whilst the auxiliary burners keep the former hot, for starting afresh.
4. The burner can also be cut off when descending a hill.
5. The expenditure of heavy petroleum, which can be obtained in this country at from 3d. to 4d. per gallon, would not, on the average, exceed in the case of a carriage such as described, 1½ gallons per hour when carrying four people at a speed of twelve miles per hour on average roads.
6. The weight of the carriage unladen will not be greater than one ton.
7. Six minutes only are necessary to prepare the carriage for running, and being free from all complications, any intelligent man can drive it.

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There are several points in connection with steam carriages which cannot be over-rated, and greatly to be appreciated, by those who have been in the habit of using petroleum driven motors. The chief one is that the crawling process up a hill is dispensed with, and twelve miles an hour up the steepest hill which horses and carriages at present climb can be obtained without an effort. Secondly, when stopping and starting in the traffic, the engine is stopped and started as would be done in the case of a horse. Since the whole of the steam is condensed, none of it passes into the atmosphere. Should by chance any do so, being superheated, no vapour escaping is visible, and days may go over before it becomes necessary to take in a fresh supply of water to make up for any slight waste there may be.

There are no valves to grind, no cylinders to clean, no inflammable material to store at home or carry when on a trip, no unpleasant smell is produced, there is absolute freedom from vibration, no chance of a breakdown when least expected, no accumulator to charge, or platinum points to be renewed, no ignition lamps and tubes requiring attention and occasional renewal; all repairs that may become necessary at any time, the carriage builder, or even the village smith, can carry out.

Quite apart from the advantages mentioned there is another which is of great practical importance, and is, that any moderately intelligent man, with a few hours' instruction, becomes master of the engine and carriage.

It is possible to find men who have been accustomed to steam engines in large numbers. There ought, therefore, to be no difficulty in finding a supply of drivers in proportion to the demand. This is not the case with oil driven vehicles, on

account of the complexity of the working parts, combined with a quality unknown to the steam engine—that of developing some new defect when least expected.

Complete success can be obtained by this means, but only by the introduction of great complication in valves and gear, so that in practice it is probably more convenient to be subject to vibration in an oil or gas motor carriage when running at low speeds, than to incur the risk of difficulties which must arise with still more complex machinery. When oil motor carriages are running at a moderate speed the vehicle becomes the flywheel, and the greater part of the vibration disappears, but there is no means of obtaining regular and steady motion at slow speeds, however good the governor may be. There will always be a tendency for the engine, when the full power is not necessary, to run faster than the governor allows, and the speed is arrested. This action keeps on repeating itself, consequently the carriage advances by fits and starts. The oil motor carriage is only comparable with the horse drawn vehicle for comfort, when running at high speeds. With steam, compressed air, and electricity, these disadvantages are completely absent, likewise the necessity of a clutch, or its equivalent.

I have made some experiments with my oil motor carriage on roads covered with snow and ice. It is known that many possessed of such carriages have traversed portions of Switzerland and elsewhere covered with snow. I am ready to admit that such carriages, lightly laden, travel well over snow, but after a thaw succeeded by a frost, hill climbing becomes a dangerous proceeding. I have found on several occasions, although the motrice wheels were revolving, the carriage bodily slipped backwards, and naturally no brakes are of any avail under such conditions. I took the safest course at such times, and turned the carriage gently into the hedge, and waited for help, or procured sand to get a grip on the road. It is evident also, under such conditions, the power of the engine is not a factor in the case.

I would strongly recommend possessors of these carriages to supply themselves with an ice brake, similiar to that which I have put on my own carriage. It consists of two rods of iron with prongs at the free ends, the other ends of the rods being hinged to the carriage. When mounting a hill covered with ice, the rods are lowered to the ground, and if by chance the carriage cannot advance, the spikes at the free ends of the rods stick into the ground and prevent an accident. The break is inclined at an angle of 45 degrees to the road when resting on the ground. Ice wheels may also be required in some climates.

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Finally, the best existing motor the world has yet seen, for its power, method of fueling, suspension springs, and traveling long distances before recharging, is one which is likely to remain with us for many a long year to come, whatever may be the future

development of motor-traffic. It is known and loved by all, young and old, under the name of the Horse.

OFFICE OF
DURYEA MOTOR WAGON COMPANY,
36 Wilbraham Road, Winchester Park.

SPRINGFIELD, Mass., U. S. A., June 4, 1897.

MR. NELSON L. LITTEN, Secretary Western Society of Engineers,
1737 Monadnock Block, Chicago, Ill.

DEAR SIR: Replying to your esteemed favor of the 25th ult., we are pleased to enclose herewith, as requested, a few words concerning our type of motor vehicle. Thanking you for the attention, we are,

Very truly yours,
DURYEA MOTOR WAGON COMPANY.
Per GEORGE HENRY HEWITT, President.

FIG. 206. Duryea Motor Wagon.

SPRINGFIELD, Mass., U. S. A., June 4, 1897.

GENTLEMEN: It is with pleasure that we submit a few facts regarding our motor vehicles and our experience with them up to the present time.

We originally undertook and have thus far persevered in the problem of a driving vehicle rather than business vehicles.

This problem we believe more difficult than the business vehicle problem, because the requirements of the pleasure vehicle are more varied.

Our pleasure vehicles are handled by private gentlemen who do not care to become or look like machinists while they are handling their carriages, and for them the carriage must be easily operated, easily maintained and cared for, neat and pleasing in appearance, comfortable to use and capable of a wide range of speeds and conditions.

It must be able to make long trips or short trips at the convenience of the driver, adapted to bad roads and hills as well as paved streets.

The business vehicle may do its work within a given radius, and that prescribed radius may not contain sufficient distance or severe enough hills or bad roads to tax the ability of the vehicle.

Further, the business vehicle is in the hands of a man who manages it not for his own pleasure, but for pay.

That he may manage it, he will, if required, secure the necessary mechanical ability to properly care for it, and will not refuse to act as a machinist if occasion demands.

Again, the requirements of a business vehicle in the matter of speed are not great.

The speed of the business horse will not exceed seven or eight miles per hour except in very exceptional instances.

The pleasure horse, however, is expected to have a speed of "2.40 on a plank road" or better, and the motor vehicle must be able to be well up to this, or even better than this, if it is to meet the requirements and expectations of the driving public.

The difference between a mile in eight minutes and the same mile in two minutes may not look very great on paper, but in actual practice it is vast, and as many experimenters have found, all but insurmountable.

Drivers of horse vehicles who have not ridden faster than horses ordinarily take them have no idea how rough the common roads appear to be if they are driven over at twice the ordinary horse speed, and this aggravated roughness is one of the serious obstacles the motor vehicle has to overcome.

The constant shocks and wrenchings, twist, strain, loosen and break part after part unless all are properly and specially designed for their places.

For this reason, among others, motor vehicles cannot be built successfully without previous experience.

It used to be a current saying among cycle riders that no firm could build a first-class cycle their first year, and this is even more apparent when applied to motor vehicle builders.

We have continuously worked upon this problem since 1891, and only began then after considerable study and experimenting, reaching over a period of five years to that date.

Our earliest wagons, like most first attempts, we converted into junk, and proceeded to build better, until we reached an article sufficiently good to put upon the market.

These we have been showing in a limited and careful but otherwise satisfactory way, during the past two years.

We have given preference to the gasoline motor, because of its light weight, little fuel, ease of recharging, and its ability to continue in operation for a short or long period, as required.

We have had no occasion thus far to regret our choice of motor.

The electric vehicles so far shown us have been too heavy to climb hills, or venture on muddy roads, and their average distance on single charge is not greater than that of the ordinary horse, while the lack of ability to recharge is considerable, as a change of batteries is necessary, or else several hours time required.

As before stated, the motor vehicle, to please the public, must be capable of doing more than the horse.

That there are certain fields in which electricity may operate we do not doubt, but even in these fields we contend that gasoline motors are not so costly, and would be more satisfactory.

We realize, however, that the field is large, and our best wishes for success to motor vehicles of any kind are freely given.

The steam vehicle undoubtedly has fields which it may profitably work, but the objections to it prevent its favorable comparison with the gasoline motor.

The escaping steam, being visible, frightens horses, the supply of water required is quite great, and the fuel required probably twice that required with the gasoline motor; and since the fuel must be portable, the grade of the two fuels is practically alike.

The steam device has water and steam gauges to watch, has an open fire, making it dangerous around horse stables, and has many parts liable to leak and prove troublesome. Its manager must, of necessity, be an engineer; it cannot be started readily, and when stopped requires some time to cool off.

It is not necessary to criticise other methods further.

We have produced results better than those shown by other methods so far as we know, and must ask that these results be considered sufficient reasons for our adoption of the gasoline motor as our moving power.

This motor we have lightened, simplified and improved upon.

We do not use hot tube ignition because of the open fire.

Our engines are quite elastic in their speed limits, and it is no uncommon occurrence for us to use a single speed for hours at a time governing the speed of the carriage at will by throttling the engine, our extremes of speeds sometimes running as near as could be estimated from fifty up to six or seven hundred revolutions per minute.

In this respect a steam engine would be no better with the one exception that the cut off of the steam engine permits a variable amount of power to be admitted into the cylinder at each stroke, but in actual practice our engines throttle very much the same as a steam engine having a fixed cut off.

We have built reversible engines, but do not find it advisable to do so.

Our muffler experiments have produced a very satisfactory device for stopping noise, and we doubt if our vehicles are more noisy than any other system of power.

We have, on one occasion, compared them with two different

makes of electric vehicles, and the roar of the gears used by the electrics proved much noisier at high speeds than any noise produced by our wagons.

This was contrary to our suppositions, and was a surprise to us as well as others.

Our steering devices secure us almost a bicycle steering. The effort required is little and the control positive. It can only be appreciated by use on bad roads at high speeds. Our control is vested in the same lever as the steering, and since the operator must continually steer, this insures a hand on the control constantly. The result is a very fast vehicle, safer and more manageable than a horse.

We have been and are working on other problems, such as business vehicles and boats, and while we are not yet prepared to make public our results, we feel confident that they will be fully as successful as what we have already shown.

To give some idea of our present work, we can say that our latest type of pleasure vehicle seats four people, weighs eight hundred pounds ready to run, and is capable of a mile in two minutes for a period of several hours.

We do not regard this as final, however, and are pushing forward toward still lighter and still faster vehicles as well as toward the heavier business fields.

MORRIS & SALOM,
926 Drexel Building.

PHILADELPHIA, June 1, 1897.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

GENTLEMEN: Replying to your favor of the 25th inst., it may be of interest to your society to know that on March 29th the Electric Carriage & Wagon Co. established the first Motor Vehicle Station in the world at 140 West Thirty-ninth street, New York City, and since that time have had in daily service twelve electric hansoms and one surrey. Engagements may be booked ahead the same as at any ordinary livery stable, as the station is open at all hours of the day and night and has telephone connection.

The success of the station has been almost instantaneous as at the time of writing, just two months after opening, it is on a self-sustaining basis. During the month of April (and the first one of our operations) the hansoms covered 2,000 miles and carried nearly 1,000 passengers. The increase for May will be nearly fifty per cent.

Notwithstanding the difficulties of starting such a new and radical innovation as the motor vehicle, and the breaking in of inexperienced men for drivers the accidents have been few and the delays trifling. The service is meeting with the highest commendation from the public, and we already have quite a number of

regular customers which, of course, is the best evidence that the service is satisfactory. We are now considering the advisability of adding twelve more hansoms to our present equipment.

Yours very truly,

ELECTRIC CARRIAGE & WAGON CO.

BY MORRIS & SALOM.

As the motocycle to be commercially successful must compare favorably in cost of operation with the horse, an attempt was made to get some reliable data as to the cost of operating modern first-class delivery or express wagons in a large city. The following replies speak for themselves and give interesting information.

Messrs. Chas. A. Stevens & Bros., in reply to a request as to the relative cost of operating the electric delivery wagons they now have in service, as compared with horses, replied as follows:

CHICAGO, ILL., August 31, 1897.

H. M. BRINCKERHOFF, 258 Franklin street, City.

DEAR SIR: Replying to yours of August 30, will say that any figures that we would give you now concerning the comparative cost would have to be approximated, therefore you can get them about as well as we can. Would state, however, that the best conducted barns of today, whose wagons travel the distance ours do, require about four teams to each wagon, i. e., driving a team one-half day every other day. Our wagons are now running from sixty to eighty miles per day, which would, under that plan, give each team from thirty to forty miles to do.

As to the cost of keeping teams, you can arrive at that as well as anybody, and as to the cost of running our wagons, we can, after we receive our first month's bill, tell exactly, but we think it will be less than thirty cents per day.

Regretting that we cannot answer you more clearly, we remain,

Yours truly,

CHAS. A. STEVENS & BROS.

The following communication in reply to a letter asking the cost of keeping horses on a large scale for express service was received from Mr. Frank H. Hebard, of Hebard's Warehouse & Van Co., Chicago, Ill.:

CHICAGO, Sept. 7, 1897.

H. M. BRINCKERHOFF, Chicago, Ill.

DEAR SIR: In answer to your inquiry in regard to the operating expenses of an express wagon, will say that the care, feed, shoeing, etc., will average, as near as can be estimated, about 40 cents per day for each horse.

How near to perfection they have the motocycles I do not know, but what information I have had, I consider them a very

good thing and believe they will be used sometime in the future on the express wagons drawing about 2,000 lbs.

Hoping that this will enlighten you a little on the subject you are asking, I am,

Most respectfully,

FRANK H. HEBARD.

DISCUSSION.

Mr. L. L. Summers: I would suggest that, perhaps, if the members are not familiar with the operation and control of these vehicles we have some rough prints, which do not go into details, but perhaps a few minutes exposition would make matters more clear.

As is well known, the gas engine will not start under load, nor will it start by simply operating a valve as in the case of the steam engine. For this reason the engine, as applied to vehicles, is not connected directly to the driving wheels, but is arranged so the engine can be started, and when in full operation the load can be thrown on. For the purpose of speed control, etc., it is convenient to use a counter shaft, through which the power is transmitted to the driving wheels. The engine drives this shaft through some form of clutch or belt shifting device. The engine is started by the operator giving the engine hand-wheel or crank shaft a few revolutions, and the cycle is thus inaugurated as in the ordinary engine. The operator may then control the vehicle from the seat by throwing the transmitting mechanism into gear.

There are two general forms of vehicle as driven by the gas engine. One of these uses belts, and ordinarily has two speeds controlled by pulleys of different size; all intermediate speeds are obtained by altering the mixture supplied to the engine and thus varying its speed. The other general class keeps the speed of the engine constant, and by combinations of gears the various ranges of speed are obtained. A clutch is used to put the vehicle in motion in the geared type, and in the belted type the belt is shifted from a loose pulley to one of the driving pulleys.

There are some friction drive machines, but these are quite diverse as to form and are hardly to be considered a general form as yet. The connection from the counter shaft to the driving wheels is almost always by chain and sprocket. In order to allow for the difference in travel of the driving wheel when rounding curves or traveling uneven ground, the wheels are not rigidly connected but are driven independently by a modification of the differential gear; this allows the wheels to adjust themselves to the requirements of unequal travel. There are many details and modifications to be considered in designing a vehicle, but these rough sketches show the principal elements of control.

Mr. J. C. Bley: I would like to ask Mr. Summers, when he speaks of belt, does he mean always the chain gear or just friction belt?

Mr. Summers: I mean a two-inch to four-inch friction belt, not a chain gear; they utilize the slip of the belt to ease off the jar and strain in starting.

Mr. B. J. Arnold: I would point out one difficulty of this jack-in-the-box, as it is called by mechanical men; perhaps some of you have observed the same thing. If one of the driving wheels chances to strike a mudhole and goes down, and the other wheel remains on solid ground, the wheel in the mud will revolve with twice the velocity that it ordinarily does when traveling along the road, and the other one will stand still. The effect of this is for the revolving wheel to dig deeper into the soft place and the vehicle does not advance. To obviate this difficulty the builders of traction engines provide holes through both gear wheels so that bolts can be placed through in order to couple the wheels rigidly together. That is very often necessary in soft roads.

In some of those communications I noticed that storage battery was criticised somewhat severely on account of the time it requires to charge it. That has been a mistaken notion until recently; in other words, we find that we can charge the storage battery in a very short space of time if it is desirable. They are often charged in as short a space of time as one hour, sometimes in forty minutes, but it is not desirable to charge them as rapidly as that, because it shortens the life of the battery somewhat, but it is practical if conditions require it. It is only a question of the cost of renewing the battery oftener against the desirability of charging it at a more rapid rate. The efficiency on rapid charging and discharging does not drop off as rapidly as has been heretofore supposed by many. The capacity of a given battery decreases quite rapidly in proportion as the rate of charge and discharge increases, but the efficiency is not lowered so rapidly.

In regard to the respective fields of the steam engine, the gasoline engine and the electric battery carriage, it appears to me that for traction work for heavy loads on fairly good roads, for instance, across country hauling, that the steam traction engine is bound to hold its own. It is less complicated than a gasoline engine and meets a condition that the gasoline engine is not able to meet on account of its being able to start under a heavy load, as is often required on hills. For long distance riding, however, on average roads, I believe that the gasoline engine is pretty sure to be the coming motor, but for boulevard work in cities and for country roads that are well paved or macadamized, the electric carriage will come and will hold its own. For pleasure riding on the boulevards in the city, no one wants to bother with a steam or gasoline engine if they can get something that is easier to operate, and the electric carriage meets the requirements. When the country roads become macadamized more generally than they are at the present time in this country, I believe the electric carriage will reach out into the country traffic and become more popular for that class of work.

I have my friend here, Mr. Condict, general manager of the Englewood & Chicago Storage Battery road, which is now in operation, and the construction of which he had charge of as engineer, and I would like to have you ask him questions. I want to say that Mr. Condict has been building storage batteries for railroads for the last twelve years, and ought to know what he is talking about.

G. Herbert Condict: Some weeks ago I was talking to a prominent man of one of the street railways in this city, and he made the remark that he would be sorry to see that any friend of his had gone into the storage battery traction business, and further, that such a man he would consider a fool. So I feel, when spoken of as a man connected with storage battery traction, as if I was rather looked upon with pity, because the history of storage battery traction in this country, up to this time, has been a "tale of woe." Failure after failure has been the result of experiment and test and hundreds of thousands of dollars have been spent, and yet, today, there is only one road operated by this system in the United States. But when we consider that everything that was necessary in getting up a car for operation had to be specially designed, that the motors were built, that even some of us built the car bodies and the car trucks, and that the controllers were continually burning out and so on, and that all those things in every case were charged to the storage battery, we come to the conclusion that possibly the battery was not the only trouble that we had to overcome.

On the road in this city we have eliminated all these factors which would tend toward failure, so that the battery would have every possible opportunity to demonstrate its capability. The motors are specially designed for the work, and are working efficiently and without giving any trouble. The steam plant has been designed so that we get power at the most economical point and the controllers are not continually melting up, as was the case in former trials. This road has been in operation since the 1st of January, 1897, and the cars are now running about 3,000 miles per day. The batteries which were put in service on the 1st of January are still doing work, not having cost anything for maintenance. Some of them have performed over 7,000 car miles, and this is certainly cause for congratulation, so we think. The only experience in motocycles that I have had has been in street railway work, but I feel that the difficulties which we have overcome in street railway traction (which were greater possibly than those of the vehicle which runs on smooth pavements in cities and on good roads) are assisting in solving the problem of securing a motocycle run by electricity. Without going further into the question at this time, I would be very glad to have you ask questions. Some time in the near future I hope to extend to this Society an invitation to visit our plant and to examine it most thoroughly.

Mr. Arnold has spoken of the weight of the power for horse power, which on our car is about 144 pounds per horse-power hour. That is greatly reduced for motocycles running in New York and other cities, but the great question—the maintenance of the battery—is still to be solved. We have not had any charge for maintenance so far, so we do not know what it costs, but in the course of a few months we will be able to give accurate figures.

J. S. Stephens: I would like to ask if he has any figures to give on economy compared with trolley work

Mr. Condict: I was just preparing to make a test, but at this time have no figures with the exception of some rough estimates which we have made, that we were operating at somewhat ss than Kilo Watt hour per car mile. We expect to get our power for less than two pounds of coal per horse-power hour. Last Sunday we carried about 14,000 people, and we estimate hat the horse-power required for operating was about 14.58 per orse-power hour per train of from two to four cars.

Mr. Arnold: I would like to comment on that. Now take that basis on fifteen horse-power at the power station, that would mean on a trolley line about eight horse-power delivered to the motor car; the rest would be lost in the transmission and in the gearing of the motor and the electrical losses in the motor, say 35 to 40 per cent loss. But this represents the total energy produced delivered to the cell; it takes care of all losses. We are endeavoring to get facts that we know we can depend upon. These facts are correct up to date. We may at a later date be able to give you reliable data in all details.

Mr. Summers: What proportion of the fifteen horse-power was available at the rim of the wheel on the motor car?

Mr. Arnold: That would be only a guess on my part. I would surmise that the loss of the battery is about 30 per cent; the balance is in the gear of the motor.

Mr. Summers: Then you have got a lower percentage available at the rim of the wheel than you would in a trolley?

Mr. Arnold: No, I think the percentage is nearly the same. You have on this trolley about 15 to 20 per cent loss in operating that many cars and you have the same losses in your motor and gearing that we have, consequently it is the battery loss against the line loss. Now if your line loss is less than 25 to 30 per cent, then the trolley line is more efficient; if it is equal to it, it has the same efficiency.

Mr. Summers: Then your battery loss is about 30 per cent?

Mr. Arnold: I have guessed that. I do not think it would be more than that, possibly it would be a little better. It is what we expect. We know it is that in the auxiliary batteries used in the station. Judging from the record at the power station, we think it does not exceed that very much.

Mr. Summers: Is there any approximate cost per Kilo Watt hour?

Mr. Arnold: Really, I do not know without thinking a little. We can tell you that I suppose in thirty days. We have a triple expansion Williams engine and the most approved generators we could get, and carry 185 pounds of steam. We believe for that plant we could produce a horse-power hour on two pounds of ordinary coal, but cannot yet tell.

Mr. Summers: I would like to add that I believe the principal problems in motocycles are largely details of design. There are many elements that enter the problem which seem never to have been treated scientifically. There are a great many things that carriage makers seem to have determined by instinct. For instance, the carriage manufacturers today have what they call a gather to the wheels. They set your wheel forward a little bit, so that when the draw comes on the reach-bar the wheels straighten out and are true with the axle. Then they have what is called dishing the wheel. It is known, of course, that in ordinary axles leather washers are used as a collar between the steel box and steel axle, and if they are not put in they will grind out the steel axle in very short order. In testing some axles it was found that the wheels would make from six to seven revolutions and would screw to the head of the axle until the stress in the spokes and felloe was equal to the friction between the axle and the box, when they would spring back to place only to repeat the operation, each time consuming energy in the inward friction.

Sir David Salomons makes the statement that he believes that a solid rubber tire may be preferred eventually to the pneumatic tire. The saving effected by the rubber tire is usually in the axle and not in the tire. Delicate tests were made and axle friction was successfully isolated from the friction of the tire on the surface of the ground, and it was found that the solid rubber tire would allow a wheel to adjust itself to the bearing and thus prevent a binding action. A pneumatic tire was slightly superior, but very often the increased friction between this tire and the earth would offset the diminished friction in the bearing, so that in many cases the solid rubber tire is superior to the pneumatic tire; the pneumatic tire's greatest advantage is on uneven roads, where it will obviate lifting the whole vehicle over some small obstacle by allowing the obstacle to sink into the tires. But if you do not have to lift the vehicle over these obstructions, there is no particular gain in the pneumatic tire over the hard rubber.

XVI.

EXCURSION TO THE EAST.

Report by ISHAM RANDOLPH, Mem. W. S. E., Chairman Committee on Entertainment.

Read October 20th, 1897.

To the Western Society of Engineers.

GENTLEMEN: After many months of inaction, your committee is at last able to report as a fact accomplished a pilgrimage under its auspices from Chicago to New York and return. It would be more in accordance with absolute fact, however, to say that that portion of the pilgrimage between Niagara Falls and New York was under auspices so hospitable, so generous, yea, so princely in conception and arrangement that your committee cannot find words to express its appreciation of all that was done for the comfort and enjoyment of the pilgrims. Our special train of seven Pullman coaches pulled out of Dearborn station at about 6:15 on Wednesday, the 22d of September, with a company of one hundred and eighty odd souls aboard. Fearing that some might have hurried off without an evening meal, we had a stock of Technical-Club sandwiches in the baggage car which served as filling for sundry aching voids scattered throughout the train. Our stop for breakfast was at Hamilton, Ont., where the provision was abundant but the seating capacity of the dining hall was inadequate. This was an occasion of discomfort to those who were obliged to stand and gather the fruitage of the lunch counter, but none came away hungry. At Suspension bridge we were met by Mr. Alfred Noble and Mr. Chas. L. Harrison of our Society. After a short halt on the Canada side our train pulled on to the great steel arch bridge, spanning the Niagara river, and stopped for some minutes, giving us an opportunity to view that impressive scene which has nowhere its parallel in nature; on the distant right was the grand sweep of the American and the Horse Shoe falls, thinly veiled by the mist cast off from the plunging, seething torrent. On the left far down below us in the gorge the fugitive waters from the upper lakes surged and billowed in the narrow channel as they swept onward to lose themselves in the calm depths of Ontario, while beneath, bearing us up, was the great bridge, its steel ribs overarching the torrent, springing from nature's adamant buttresses on either side. This bridge was built by the Pennsylvania Steel Co., on the design of Mr. L. L. Buck, chief engineer of erection. Its span is 550 feet with a deck span of 115 feet at each end, and its height above

water is 226 feet. The top floor, 35 feet wide, carries the two tracks of the Grand Trunk Railway. The lower floor is 57 feet wide and its roadway affords team track, electric car track, and sidewalk. The weight of steel in the structure is 7,200,000 lbs., about 5,000,000 lbs. of which is in the arch span.

This structure was completed in March last and the old suspension bridge which it replaces has been taken down since that time. The old structure was erected in 1855 and was one of the most noted of its type. Your chairman was at the site in April last and saw the work of removal in progress. The preservation of the cables was excellent, the wires being bright and free from rust apparently as when erected forty-two years before.

"Still they gazed and still the wonder grew" until time was called and we were whisked away to the Niagara depot, where we disembarked and marched with one consent to the Cataract house. There a capacious dining-room received us and a generous meal was spread for our delectation. Our fellow member, Mr. Charles L. Harrison, who was on the spot, had, at our request, made all necessary arrangements for our meals while at the Falls, and that they were on lines of profusion and excellence no one who sat at those hospitable boards can deny. After lunch the majority of our pilgrims visited the plant of the Cataract Construction Co., but for some, this first opportunity to view the falls, the rapids and the whirlpool wrought so grandly by nature's God proved a temptation which overmastered all desire to see man's feats of civil, mechanical and electrical engineering, wonderful though they are. The power plant was thrown open to us and every opportunity was afforded us of seeing the machinery and learning of its construction and the magnitude of the plans for its ultimate development. Three wheels are now installed, built by Morris & Co., Philadelphia, on the designs of Faesch & Picard, of Geneva, Switzerland, to whom the award for the best design was made as the result of a competition in which three Swiss, one Austrian, four French, three English and two American firms participated. Water is conveyed to each wheel through a penstock 7′ 6″ in diameter. The fall measured from water level in head race to center of wheel is 136 feet. The inner radius of each wheel is 31½ inches and the outer radius 37½ inches. Merriman gives the theoretic development for each wheel as 6,645 horse-power, and his concise description in Art. 164 of his Treatise on Hydraulics gives in few words a very clear idea of the hydraulic end of this plant. The electrical development for each wheel is rated as 5,000 H. P. The field magnate revolving around the armature was, I believe, used here for the first time. The field ring of nickel steel is 11′-7 3/8 inches outside diameter; thickness, 4 11-16 inches; depth, 4′-2¾ inches; weight, 28,840 lbs.; tensile strength, 83,000 lbs.; elastic limit, 53,000 lbs.; elongation, 27 per cent (see Journal W. S. E., page 733, Porter). The water after passing through the wheels is discharged into a tunnel 20 feet in diameter and escapes into the Niagara river at a

point below the American falls, 7,000 feet away from the power plant. The initial outlay has been made for an eventual development of 150,000 H. P., and the work of enlarging the plant is now in progress. E. D. Smith & Co., who, owing to their work upon the channel of the Sanitary District and upon many other important engineering works, have earned national and enviable renown, are just completing an extension of the wheel pits. This extension is 284 feet long, 20 feet wide and 135 feet deep; it will receive seven wheels, adding 35,000 H. P. to the present potentiality of the plant. One hundred and forty-three feet of this cut have been made through solid lime rock of a hardness which reduced the record of channeling machines whose daily task on the Sanitary channel was 100 square feet per day down to about 30 square feet. The lower 30 feet of the cut is in shale. Through the courtesy of Mr. J. M. Jackson, one of the E. D. Smith Co. firm, two of your entertainment committee and three other pilgrims were permitted to go to the bottom of this incision into the bowels of mother earth. Two traveling rotary derricks remove the excavated material from the cut and deliver the brick, iron, etc., used in the work. Entering one of the material skips operated by the derrick, we were swung over the chasm and quickly lowered to the bottom which, when we reached it, seemed a long way from daylight. On the river side of the cut we saw four tunnels or chambers arched and lined with brick, running back 38 feet from the face of the cut; they are 16 feet wide at the springing line and 19 feet high; in these we learned that pumps are to be placed, which, operated by the flue of a column of water, will supply the city of Niagara with its drinking water. A well defined contraction of the width of this deep cut has been detected and to prevent this movement cast iron bed plates, each weighing two tons, are being set opposite each other, and between these cast columns, each weighing five hundred tons, are placed to take the thrust. A number of these separators are to be used, and they are reinforced by cross-walls at intervals. The girders which are to carry the floors of the several galleries, and also form guides and supports for the shaftings, are carried upon massive cast brackets let into the solid rock of the sides. The estimated weight of iron thus used is 2,000,000 lbs.

For the courtesy shown us by Dr. Coleman Sellers, president and chief engineer, and W. A. Breckenridge, assistant engineer, and each member of the staff of the works, we, the recipients will entertain a lasting appreciation.

So little of daylight was left to us when we returned to the Falls that our company could not be induced to devote it to further inspection of man's mighty works, and they lost no time in boarding "Gorge railway cars" and taking the down grade for Lewiston, a ride which affords the finest view of the rapids, the whirlpool and the towering cliffs, whose monumental heights have watched through 50,000 years (if the testimony of the rocks may be relied upon), the fury of the waters as they eroded for them-

selves the gorge through which they flow. Your chairman was left to profit by the courtesy of the Niagara Falls Hydraulic Power & Mfg. Co., and under the guidance of Mr. Shepherd, assistant engineer of that company, he made an inspection of their plant. This company possess the results of the earliest efforts to utilize the falls for power purposes upon a large scale. They take water through an open canal from a point, I should say, three-quarters of a mile above the American falls, and utilize it at a point a mile below the falls. The Niagara river is their tail race, and the difference in level between the head and tail race is 220 feet. They are now developing about 7,500 horse-power, and plans are in process of erection for two additional developments of equal or greater power. The penstock now in use is eight feet in diameter, and one of those upon which work has been commenced is eleven feet in diameter. He found this plant of very great interest indeed, but during the time at his disposal was unable to master the mechanical details of wheels, governors, dynamos, compressors, etc. The power now developed operates the work of the Pittsburg Reduction Co., the Cliff paper mill, the Gorge railway and one or more other railways. We had the pleasure of having Mr. W. C. Johnson, chief engineer of this company, with his charming wife and his associate, Mr. Shepherd, dine with us at the Cataract house, and after dinner they piloted us back in a body to the works, and we examined them by electric light. This ended our sight-seeing at Niagara, and at 10:15 P. M. we boarded our sleepers, and in short order became sleepers ourselves. The name of the car in which your chairman was

FIG. 207. Special on L. V. R. R.

quartered called to mind one of Verestchagin's pictures, "My Camp in the Himalayas." Others as they fell into the arms of Morpheus doubtless hoped that these would not prove the "last days of Pompeii."

Even the restless spirits on the Persia slept; were their slumbers deep or had they dreams of houris from the land of the Shah, or visions of the sensuous dances on the Midway in the White City, dream above all other dreams of earthly beauty.

Our morning call was to get ready for Bethlehem and break-

FIG. 208. The Special Train at Bethlehem Iron Works.

fast, and we did. At the depot we were met by Messrs. R. W. Davenport Sayer and H. F. J. Porter, of the Bethlehem Iron Co., who gave us a cordial welcome and directions as to the way we should go to get breakfast. This we found at the Wyandotte hotel a few blocks away from the depot. The line of march was along shady streets by homes set in the midst of green sward and luxuriant foliage. When we returned to the depot a train of observation cars stood where we had left our Pullmans, and as soon as all were aboard we started for a tour of the works. The two hours consumed in that tour were hours of absorbing interest. Those of us who have read the paper in the Journal of the Society for December, 1896, upon the Bethlehem Iron Works, written by our H. F. J. Porter, will read it again with a zest born of personal inspection of some of the things described, and those who never read it can do so now with interest and pleasure, because it

will prove the key to a better understanding of the wonders revealed to us as we switched back and forth from one titanic creation to another. With that masterful description easy of access, it would be presumption for any novice to tamper with the technical side of the Bethlehem Iron Works, so all that remains for us is to borrow the language of the Queen of Sheba and say that "the half had not been told us." Access to these works under such auspices as were ours would repay a journey across the continent, and words are lacking to express our appreciation of the hospitality and marked consideration shown us.

From Bethlehem we backed up to Coplay, the home of the Saylor Cement Works. There we were met by officers of the company, Mr. Wm. G. Hartrauft, president; Mr. Ralph Peverley and Mr. Seager, superintendent of the works, who piloted us first to the offices where a tempting lunch was displayed. The seductive and thirst inspiring pretzel was there in force, and libations to quench the inspiration were not wanting.

We saw the crude shale and limestone and the automatic scales used for insuring a due proportion of each in the mixture. We watched the grinding of the raw material and its mixing and conversion into machine made brick (a small proportion of natural cement is used as a mastic for these brick), saw the brick pass into the drying ovens and from thence into the Schaefer kilns, where they were burned with coal and reduced to klinker. This klinker is sorted and delivered to the grinding machinery, passing through a series of reducing processes until it finally reaches large revolving cylinders half filled with Iceland pebbles about the size of a hen's egg and exceedingly hard. When it is discharged from this cylinder after being triturated by the pebbles it is a powder of the proper fineness for use. It is then packed for shipment. These are new works and their capacity is rated at 1,000 bbls. per day. The company owns other works near at hand,but our time was too limited to permit us to visit them.

Our next run was from Coplay to Easton, where we again changed cars and were taken a few miles further to Philipsburg, N. J., the works of the Alpha Cement Co. Tables were laid in one of their warehouses, and a bountiful repast awaited our coming. As usual, we had our appetites concealed about our person ready for instant use, and it was not long before every craving was satisfied, whether that craving was for liquid or solid sustenance. After being thus refreshed, we made the grand round of the works under the guidance of the president, Mr. Geo. E. Bartol; Mr. Newberry, chemist; Mr. J. W. Donaldson, general sales agent; Mr. Alfred Thorn and our own indefatigable host, Mr. J. W. Dickinson.

Beginning at the quarry from which the shale is taken, we followed the raw material through the process of mixing in proper chemical proportions of limestone and shale, grinding to powder, which passes into the rotating kilns where it is burned, oil and fine coal dust being the fuel used. These kilns are cylinders

FIG. 209. Alpha Cement Rock Quarries.

about sixty feet long, set at such an angle with the horizon as to cause the contents to move slowly from the supply end as the cylinder revolves to the discharge end from whence, when thoroughly roasted, it falls to the floor below as klinker, rather uniform in size and about as large as marbles. As soon as this klinker cools it is ground in Griffin mills and is then ready for shipment.

Mr. Newberry took a small party of us into the laboratory and showed us how they determined the proper proportions of limestone and shale for their mixture, and explained how they maintained these proportions.

We were shown a house built of brick and artificial stone made from sand and Portland cement. The desired color is given to the product by using a facing of sand obtained by grinding stones of the shade desired. These brick are very perfect and present an exceedingly handsome appearance in a building.

When we got back to Easton we found ourselves the guests of the Ingersoll-Sergeant Drill Co., and one would think from what we received at their hands that they are organized, among other things, to entertain with princely elegance and feudal hospitality. Electric cars stood ready for us and word went around that our destination was Paxinosa mountain. The name, then new to most of us, will serve ever more to conjure up landscapes of grandeur and beauty which will never fade from the canvas of memory. For a part of the way our track was through the quaint

FIG. 210. Paxinosa Inn, Easton, Pa.

old town of Easton; up grades which would seem to justify or rather to demand a rack railway, but up we went, rack or no rack. Clearing the town, we began to climb the mountain side, and the scenery, sublime and beautiful, soon beggared the party of its adjectives and left them, when they reached the summit and climbed higher yet to the observation tower of the "Paxinosa Inn," with only dumb admiration for what they saw. Far down below was the silver thread of the river, while to the north and west range upon range of mountains met the horizon with their billowy lines, while in between lay a valley whose well fenced farms and comfortable homes bespoke its richness. To the southeast, completing the picture, lay the town of Easton with its LaFayette College, where the sciences of our profession are so ably taught, looming above all other buildings. But the shadows fell so fast that the feast of vision was soon over and we came down to earth again to be welcomed in the reception hall by our entertainers and made acquainted with a delegation whom they had brought out from New York to meet us. The ball room was ablaze with lights, and music lent its melodious pleasings to the ear, inviting the lovers of the light fantastic to trip a measure, an invitation which had many responses. Soon we were led on to the great dining hall where the tables, adorned with fruits and flowers, betokened a bounty of good things to come, and they came. Mr. W. L. Saunders, of New York, vice-president of the company, was the master of ceremonies, and in fitting season addressed the company in most felicitous strain, ending with a toast to the Western Society of Engineers and the fair women of the West. Our president responded to the toast, and on invitation, your chairman made a few remarks. Mr. Hartzell, mayor of Easton, favored us with words of welcome; then Mr. Saunders told us of the woman and her daughter who spent their appointed time at the Columbian Exposition, and to make sure of not missing anything staid over another week. On their way home they overheard a group of ladies discussing the Exposition, and one of them said that what impressed her most was its "tout en semble." The girl said, "There, mother! I knew we would miss something, we did not see that." He went on to say that he would not have us return to Chicago without seeing and hearing from the tout en semble of the engineers of the East, Commodore Henry Loring, president of the Engineers' Club of New York, whom he then presented. The Commodore addressed us briefly and wittily, and after three cheers and a tiger for the Ingersoll-Sergeant Co. we returned to our cars and coasted through the darkness down the mountain side and finally landed at the gates of the Ingersoll-Sergeant Co.'s works. They were illuminated and the machinery was in full blast. These works cover sixteen acres of ground and their equipment is most complete in all departments. Here electricity has no function beyond illuminating. Steam compresses the air and the air does all the rest, operating hoists,

MENU

Blue Points

Consomme Royal — Small Patties, Financier

Sliced Tomatoes

Soft Shell Crabs on Toast

Fillet of Beef, a la St Hubert — Tomato Farcies

Lobster Salad, en Mayonnaise

Roman Punch

Spring Turkey, Stuffed, Currant Jelly

Mashed Potatoes — Corn on Cob.

Apple Dumplings, Cream Sauce

Lemon Meringue Pie. — Vanilla Ice Cream.

Assorted Cakes.

Cheese — Banquet Wafers

Fruit — Coffee

PAXINOSA INN--S PROSKEY

WESTERN SOCIETY OF ENGINEERS

EASTON, PA., SEPTEMBER THE 24TH, 1897

THE INGERSOLL-SERGEANT DRILL COMPANY

FIG. 211.

FIG. 212. The Delaware Valley from Paxinosa Inn.

great traveling cranes, pumps and every sort of thing which can take motion from a piston.

After looking these works over and seeing the largeness of the scale on which they are run and taking a mental inventory of the output in drills, channeling machines, compressors, etc., one realizes that if these be taken as a partial measure of the amount of public work in process of construction, the aggregate volume of that work must be prodigious indeed.

When we said good-night to the works it was not saying good-bye to all of their creations, for, as will be learned later, we met them again in New York.

We feel that the prime instigator and abettor of the hospitalities extended to us by the Ingersoll-Sergeant Co. was our fellow member, Chas. W. Melcher, and we will lay it up against him as a debt of lasting gratitude.

Next door to the Ingersoll-Sergeant plant are the works of the National Switch & Signal Co., where our welcome from our old and genial friend and comrade, Chas. Hansel, was all that friendship could bespeak. There is nothing demanded by the best modern practice in signaling and railroad interlocking which this company cannot supply, and if you don't believe us, they stand ready to back up and will confirm our statement. If our good friend Sperry is here we will prove all that we have said, by him.

Human endurance fails even when the task to which it bends its energies is simply one of enjoyment, and where recreation joins hands with mental improvement the exhaustion by midnight is complete, and I venture to say that not one of us heeded the gentle whisperings of the moguls and consolidations as, with velvet tread, they patrolled the tracks beside us that night at Easton.

Jersey City was not far away when we next saw daylight, and when we stepped aboard the boats which bore us to New York, on Saturday, we were sure that a morning more perfect never lent its freshness to the harbor of the Empress City of the western world. We went as we pleased during the forenoon. By one o'clock we began to gather our clans at 100 Greenwich street, to see an Ingersoll-Sergeant four-stage compressor which furnishes power for operating locomotives on the Manhattan (Elevated) railway. We are fortunate in having a very concise and comprehensive statement of the uses of this plant put forth by the American Air Power Co., which we incorporate in our report as follows:

"The Hardie compressed air locomotive in its main features of construction is substantially identical with that of the steam locomotives in use by the Manhattan railway. Its length is the same, its driving wheels the same, but its maximum weight when manned and ready for service is less than that of the steam locomotive. The wheel base of the driving wheels being six feet instead of five feet as on the steam locomotives makes it permis-

sible to place a greater weight on the drivers than is allowaole on the steam locomotives, without increasing the strain on the structure, thus giving it increased tractive power and enabling it to take the sharp curves on the line easier. The cylinders are thirteen inches in diameter by twenty inches stroke, and the valves are specially designed. The variable cut-off is controlled by a handwheel in place of the notched quadrant used on the steam locomotives. Two independent ways are provided for applying the air brakes, and, in addition, the locomotive has a compressed air-driving wheel-brake of novel design, thus affording additional security against accident. In place of the boiler and fire-box of the steam locomotive, there is a bundle or nest of seamless steel flasks, nine inches in diameter and about fifteen feet long, having a total capacity of about one hundred and fifty cubic feet, in which the air compressed to twenty-four hundred pounds pressure per square inch is stored. In operation, the compressed air passes from these flasks through a regulating valve and is delivered at a uniform pressure into a low pressure receiver, where the air is reheated by passing through hot water and is then applied to the cylinders at a uniform working pressure of one hundred and fifty pounds per square inch. The method of storing the air, reducing the pressure, re-heating and controlling, as well as the application to the cylinder is the result of many years of study and experimental work by Mr. Hardie, whose efforts have been unequaled.

The air to charge this locomotive is compressed at 100 Greenwich street by an Ingersoll-Sergeant four-stage compressor, and conveyed by pipe line through Greenwich street to Rector street, and thence up Rector street to the Sixth avenue elevated structure, to the point where the steam locomotives take their water. It does not take any more time to charge this locomotive with air sufficient for a run to Fifty-eighth street and back than it does to take water on an ordinary steam locomotive."

At 100 Greenwich street, Mr. Henry D. Cooke, general manager of the American Air Power Co., received us, introduced us to Mr. Robert Hardie, the inventor of the air locomotive, and showed us the compressor plant which was then compressing up to 175 atmospheres and storing it in a battery of thirty Mannesman tubes, nine inches in diameter and twenty-one feet long.

At two o'clock our clans were gathering at Liberty Island dock on the invitation of our host, Mr. Dickinson, whose impression from start to finish seems to have been that nothing was too good for us, and we were soon trooping over the gang plank of the steamer Aurora, which he had chartered for our pleasure. When the last "galoot" was aboard, we shipped our hawsers and steamed up East river. Our only landing was at Brooklyn Navy Yard, where we were afforded the opportunity of boarding the man-of-war Texas, as she lay in the dry docks under repairs. Not far away was the Chicago being rebuilt after the desperate service of twelve peaceful years, and others of our warships,

torpedo boats and gunboats lay at anchor in various stages of fitness for service.

The old Andy Johnson, terror of our "unsalted seas" for so many generations, seemed even to our untutored sense of naval architecture rather a back number.

From the navy yard we steamed up through Hell Gate where General Newton put the cap sheaf to his fame as an engineer, and on past Blackwell's, Ward's and Randall's Islands, with their eleemosynary, reformatory and penal institutions. The glorious promise of the morning had its perfect fulfillment in the evening, for never were all the conditions of atmosphere and light more perfect or more conducive to the full enjoyment of the experience we were passing through. We surrendered to the enchantments of the scene and the band gave us the melodies of long ago, plaintive and tender, alternating with the songs of today's minstrelsy. The musicians somehow got the impression that of all the compositions in their repertoire "All Coons Look Alike to Me" was the gem, and most of us who couldn't turn a tune before can hum that now with our eyes shut.

We headed for the Narrows, but the pink light of evening began to fade so fast that our entertainer passed the word to the captain to put about and "pull for the shore," which we did, passing on our return almost within reach of the mighty arm of the Goddess who enlightens the world from Bedloe's island. The boat landed and so did the pilgrims, bringing ashore with them recollections which will float as gladly in their memories as did the Aurora on New York bay.

A telegram called your historian to Pittsburgh, but there was anither "chiel amang ye takin' notes, an faith he'll prent 'em." That chiel was our president, to whom we are indebted for the account of the remainder of the trip, as follows: "Several hours for breakfast at South Bethlehem gave time for enjoyment of the scenic beauties in the vicinity, environed in as fresh and delightful a morn as ever welcomed the rising sun. Not to be outdone in hospitality, the growing day brought forth Nature's most happy mood, wrapped in her most dainty gown, bidding hearty welcome at every side and extending bounteous and ever-varying entertainment until she had put the sun to sleep and roused the moon for the night-watch over her more than delighted guests.

"The Lehigh Valley R. R. evidently has a strong pull with Nature, possibly because it hauls so much of Nature's products, but probably because the railroad is 'all right.'

"Breakfast done, a rapid run through the bewildering beauties of the valley of the Lehigh river, over the mountain far above Wilkesbarre, along the cautious approach down the mountain side to that city, in full view of the broad and impressive Susquehanna valley, speeding over the gentle grades in that valley to the height at the south end of Seneca lake and thence down the whole length thereof to Geneva, the party found itself at what the commissary department of the Lehigh Valley R. R. was pleased

to denominate as a 'lunch.' 'Out of sight' does not describe it; it was good.

"Not content with having delighted the party in the extreme, a magnificent exhibition of speed was made in the run to Niagara Falls, the seven heavy Pullman cars being whisked along at the rate of seventy-five (75) miles an hour for many miles, behind one of those marvelous iron steeds which makes sport of hauling the famous Special. Thanks are due to Mr. Murray Augur, superintendent of the Buffalo Division of the road.

"Late dinner at the Cataract house, then into the hands of the Grand Trunk R. R., and at Chicago at 2 P. M., Monday."

No one who gazed upon the grand, beautiful scenery of the Lehigh Valley route will soon forget it; no words that I have heard spoken have adequately expressed our appreciation, as a body, of the extreme courtesy extended to us by that railroad through him who represented it to us, Mr. E. R. Reets. Promptness and speed characterized every train movement made between Niagara Falls and New York, both going and returning, and if anything which could have ministered to our comfort or pleasure was omitted by the railroad, we will never know it. Your committee is greatly indebted to Mr. George B. Reeve, traffic manager of the Grand Trunk railway, for kind offices and material aid in the arrangement and execution of this excursion.

The invitation to visit the Bethlehem Iron Co. was extended by the president, Mr. Robert P. Linderman, in a very courteous letter.

The hospitalities of the Engineers' Club of New York were tendered us by Commodore Loring, its president.

When it was the idea that we were to visit Philadelphia, the hospitalities of the Engineers' Club of that city were tendered us and we were invited to visit the Southwark foundry.

Another very hospitable invitation, which the limits of time at our disposal prevented our accepting, was from the American Cement Co. This telegraphic invitation, signed by Sears, Humbert & Co., was to breakfast with them and visit their works at Allentown.

Your chairman cannot refrain from expressing his own appreciation of the untiring and successful efforts of his fellow committee man, Mr. G. M. Wisner, to whose lot fell the laboring oar, and all must admit that he pulls a winning stroke.

Your president, too, being ex-officio a member of the committee, was "no dead head in the enterprise," but gave to it his best efforts, and when he does that, things move his way.

XVII.

THE DEVELOPMENT OF THE SOCIETY'S EXTENDED EXCURSIONS.

By THOS. T. JOHNSTON, Pres. W. S. E.

Read October 20, 1897.

If the development of the Western Society of Engineers during the past two years may be measured by the nature and magnitude of their excursions, there is much cause for congratulations. The excursions to Louisville and Rock Island a year ago, together with the recent excursion to New York, constitute occasions that will long be remembered and which have added greatly to the prestige and influence of the Society. There seems to be no good reason why such events should not recur year after year, and they doubtless will. This being the case, it is perhaps worth while to make some mention of the history of the past events.

Nearly two years ago, in January I believe, Mr. Ferd Hall, Mr. C. E. Billin and myself were discussing what might be accomplished by the society's entertainment committee, when Mr. Hall suggested that an excursion be made to the Bedford quarries in Indiana and he promised to see to it that transportation would form no item of expense. The proposition seemed rather bold to his companions, but was so agreeable that nothing was said to discourage the idea. Subsequent events proved that Mr. Hall measured the influence of the Society and its prestige with correct and happy foresight. Later on an invitation was secured, by myself I believe, from the Western Cement Co., of Louisville, to visit their mills. Mr. J. J. Reynolds meantime labored with the quarry owners. Along in the summer the matter was laid before the excellent entertainment committee, with results that now are happy memories of a most enjoyable occasion. Close upon the heels of this event, through the efforts of Mr. Ralph Modjeski and Mr. G. P. Nichols, the Society was invited to accept the hospitality of the Rock Island R. R., and inspect their new and excellent bridge across the Mississippi at Rock Island. Incidentally Mr. Schauffler, in behalf of the Empire Cement manufacturers, is entitled to a share in the credit for the handsome entertainment which was enjoyed on that occasion by the Society. Likewise the Government officials at the arsenal and at the Hennepin canal.

The new year brought with it a new entertainment committee having had set for them a precedent difficult to excel. They proceeded in an endeavor to arrange an excursion to New Orleans, and did some hard work in that direction, but their efforts were all thwarted by the untimely floods. Time advanced and steps

were taken with a view to an excursion to Niagara Falls and Toronto. Mr. Randolph had much correspondence in the matter, arranging for rates on the railroads, entertainment, etc. Suddenly, without warning of any kind, Mr. John W. Dickinson, of the Dickinson Cement Co., whose good business sense has dictated to him that the better informed engineers are the easier they are to deal with, came into the field, and extended to the Society an invitation to be his guests for a trip from Niagara Falls to Philadelphia or New York and return. This invitation was extended verbally to your president and afterwards to the entertainment committee in manner and form as already brought to your notice.

While Mr. Hall was the pioneer in the matter of the extended excursions, Mr. Dickinson is primarily entitled to the credit for that part of the recent excursion eastward from Niagara Falls, and to that extent the Society is indebted to his generosity. Subsequently, invitations to accept the hospitalities of others were received so numerous that it was not possible to accept all within the time available for that purpose, but of which I know we are all truly appreciative. These have been quite fully and happily noted in the report just made by the entertainment committee.

XVIII.

THE PLANT AND PRODUCT OF THE INGERSOLL-SERGEANT DRILL CO.

By CHAS. W. MELCHER, Mem. W. S. E.

The Percussive Rock Drill, which is distinctly an American invention, was first practically applied in this country to the excavation of the Hoosac Tunnel, where, on October 31, 1866, the first successful machine was put in operation. At the same time, through the persistent efforts of Mr. Thos. Doane, then chief engineer of the work, compressed air was employed as the motive power to operate the drills.

The compressors used were built under the direction of Mr. Doane, and consisted of four (4) horizontal air cylinders driven by a turbine water wheel from a central vertical shaft. The cylinders were 13″ in diameter and 20″ stroke, and the machine running at seventy revolutions per minute was able to operate nine (9) rock drills at an air pressure of thirty to forty pounds.

The drill used at the Hoosac Tunnel was the invention of Mr. Chas. Burleigh, who had acquired the right to the patents of Jos. W. Fowle, the inventor of the first machine having the drill bit attached directly to the piston-rod, and the first machine to rotate the tool by revolving the piston. Previous to this time other machines had been tried, a hollow piston drill having been patented by Mr. J. J. Couch, of Philadelphia, as early as 1849; but this machine, and its followers, up to the date of the installation at the Hoosac Tunnel, had proved impracticable for the purpose intended, frequent breakages entailing too great a cost for keeping the drills in proper working condition.

In Drinker's work on tunnelling the statement is made that the Brooks, Gates & Burleigh Drill, which was first tried on this work, was disabled at the rate of ten machines per day during the time it was employed on the work. This machine was followed by the Burleigh, which, although very heavy and expensive to keep in repair, retained its position to the end of the work. The Ingersoll drill was introduced on the west end shortly before the completion of the work.

The results at the Hoosac Tunnel gave such an impetus to the development of the rock drill that a number of machines soon appeared on the market. One of the first inventors to put a drill to work was Mr. Simon Ingersoll, who started in 1871. At this time Mr. Henry C. Sergeant and Mr. George Cullingworth had a manufacturing plant at Twenty-second street and Second avenue, New York city, where they were building water meters,

FIG. 213. FACTORY OF THE INGERSOLL-SERGEANT DRILL CO., AT EASTON, PA.

On the lines of the Central Railroad of New Jersey and Lehigh Valley Railroads, the Delaware, Lackawanna & Western R. R., Philadelphia & Reading R. R., Penn. R. R. and Lehigh Coal and Navigation Co., Canal.

presses, etc., and Mr. Ingersoll placed a contract with them to build twelve (12) drills, which were used to drive the Musconetcong tunnel on the Lehigh Valley Railroad, at West End, N. J.

From this dates the inception of the Ingersoll-Sergeant Drill Company, and from that time until the present Ingersoll and Sergeant rock drills have figured in almost every important piece of rock excavation work in the country. Since that date the company have produced more than 20,000 rock drills, over 1,000 being shipped during the past year.

From the small shop on Twenty-second street, the company moved in 1883 to a large building, corner of Twenty-seventh street and Ninth avenue, occupying four floors, and, in 1878, began the manufacture of air compressors from patterns and designs made by Mr. Sergeant. The policy of the manufacturing department has from the first been high-class workmanship and best materials. This, combined with the genius of Mr. Sergeant and his corps of able assistants, has served to make Ingersoll-Sergeant machinery a standard product.

The largely increasing demand for this class of machinery soon made still larger manufacturing facilities imperative, and, in 1893, the company erected its present plant. The new works, which cover sixteen acres of ground and are the largest, in this line, in the world, are located on the threshold of the great coal and iron districts of Pennsylvania, at Easton, on the lines of the Central Railroad of New Jersey and Lehigh Valley Railroads, the Delaware, Lackawanna & Western Railroad, Philadelphia & Reading Railroad and Lehigh Coal & Navigation Company Canal.

The class of machinery now manufactured is as follows:

Rock drills of various types and sizes, suited to the operations of mining, tunnelling and quarrying, and designed to work both by steam and compressed air.

Stone channelling machines, for use in quarrying dimension stone, and for such work as the channelled rock walls of the Chicago Drainage Canal and the wheel pit of the Niagara Falls power plant.

Gadders, used for drilling lines of horizontal holes for the insertion of plugs and feathers, and principally employed in quarrying marble.

Coal mining machines, operating on the percussive principle and designed to undercut in the coal and in the fire clay beneath the vein of coal.

Air compressors of various types and for all duties, built for pressures up to 5,000 pounds per square inch, and designed to produce compressed air under the most economical conditions known to modern practice.

Pneumatic pumps, operating on the air lift principle, for pumping from artesian wells, and, on the displacement system, for handling water under the more usual conditions.

The plant includes a brass and iron foundry, pattern shop, blacksmith shop, warehouse, tool house, and a main machine and erecting shop, the latter being 97 feet in width by 764 feet long. Four hundred and sixty feet of this length is devoted to the manufacture of air compressors, and a compressed air traveling crane of forty feet span, Fig. 214, and having the run of the entire length, does all the hoisting required in assembling and erecting

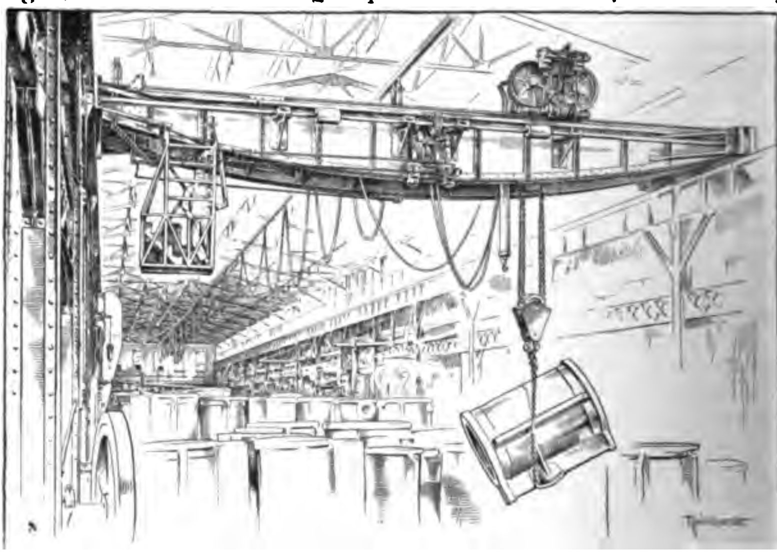

FIG. 214. Compressed Air Crane.

the compressors, and in loading the finished product on to railroad cars for shipment.

This crane is worked by three pairs of engines, each connected by piping with the operating valves in the runner's cage. The engines are of novel design, dispensing with the link motion and using instead a double set of ports to each cylinder, and a valve having a rocking motion and operated by a single eccentric. For reversing, the valve is shifted longitudinally by air pressure from one set of ports to the other. The air is conveyed to the crane from the main supply pipe by a continuous line of hose, connected by couplings in fifty-foot lengths, and, at intervals of twenty-five feet, supported by swivel blocks sliding along an overhead rail, attached to the roof truss. When the crane is at the opposite end of the building from the point of air supply, the hose hangs in loops, running in line with the overhead rail; but as the crane returns it closes the loops, and the natural stiffness of the hose turns the swivel at right angles with the overhead rail, making practically a continuous coil, each loop (twenty-five feet) of the hose occupying the six-inch space, which is the length of each swivel block. This plan of conveying the air to the crane has proved very successful, no trouble whatever being experienced.

Fig. 215. Ingersoll-Sergeant Drill Company's Works.—Interior of Foundry.

The rest of the main building is devoted almost entirely to the manufacture of the rock drill, a machine that is probably subjected to the most severe usage of any tool of equal size and weight. To be serviceable, it must stand the wear and tear with the minimum of repairs, and to make this possible the best available materials are used, and frequent tests of breaking, crushing and tensile strength and of chemical proportions maintain the standard of uniformity. This department is fully equipped with special tools designed to rapidly turn out the different parts of the rock drill, and to duplicate each part with an exactness so essential to the successful operation of machinery of this class.

In the foundry, an interior view of which is shown in Fig. 215, is another compressed air traveling crane, of the same design as the one described above, and also a "Craig-Ridgeway" Hydraulic Jib Crane, in which compressed air instead of steam is used for putting the water under pressure. Compressed air moulding machines are used.

In the cleaning shed adjoining the foundry, where the sand blast process of cleaning castings is employed, is a hand-power traveling crane with air lift. Fig. 216 illustrates the method of

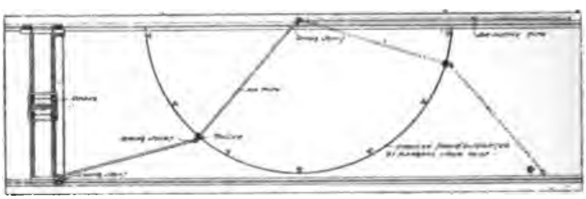

FIG. 216.

transmitting the air to the crane. Two pipes are connected by three swing joints. The center joint has a roller attached and runs on a semi-circular overhead track, having the supply joint as a center.

Compressed air for hoisting purposes in shops, foundries and mercantile establishments is now in quite general use, and if the small cost of making lifts by air were generally appreciated, very few establishments where any material has to be raised and lowered would be without it. Even with the small compressor usually installed for shop use, the cost of air need not exceed five cents per 1,000 cubic feet compressed to ninety pounds gauge pressure.

This amount of air operating an air-hoist cylinder, the appliance costing not more than $35, will lift a weight of 600 pounds 600 times to the height of four feet, or, a larger appliance, costing not more than $75, will raise seven times, a load of 5,000 pounds, to the same height.

A number of our members saw in operation at 100 Greenwich street, New York, the new type of four-stage air compressor

FIG. 217. Ingersoll-Sergeant Four Stage Air Compressor—Crank End.

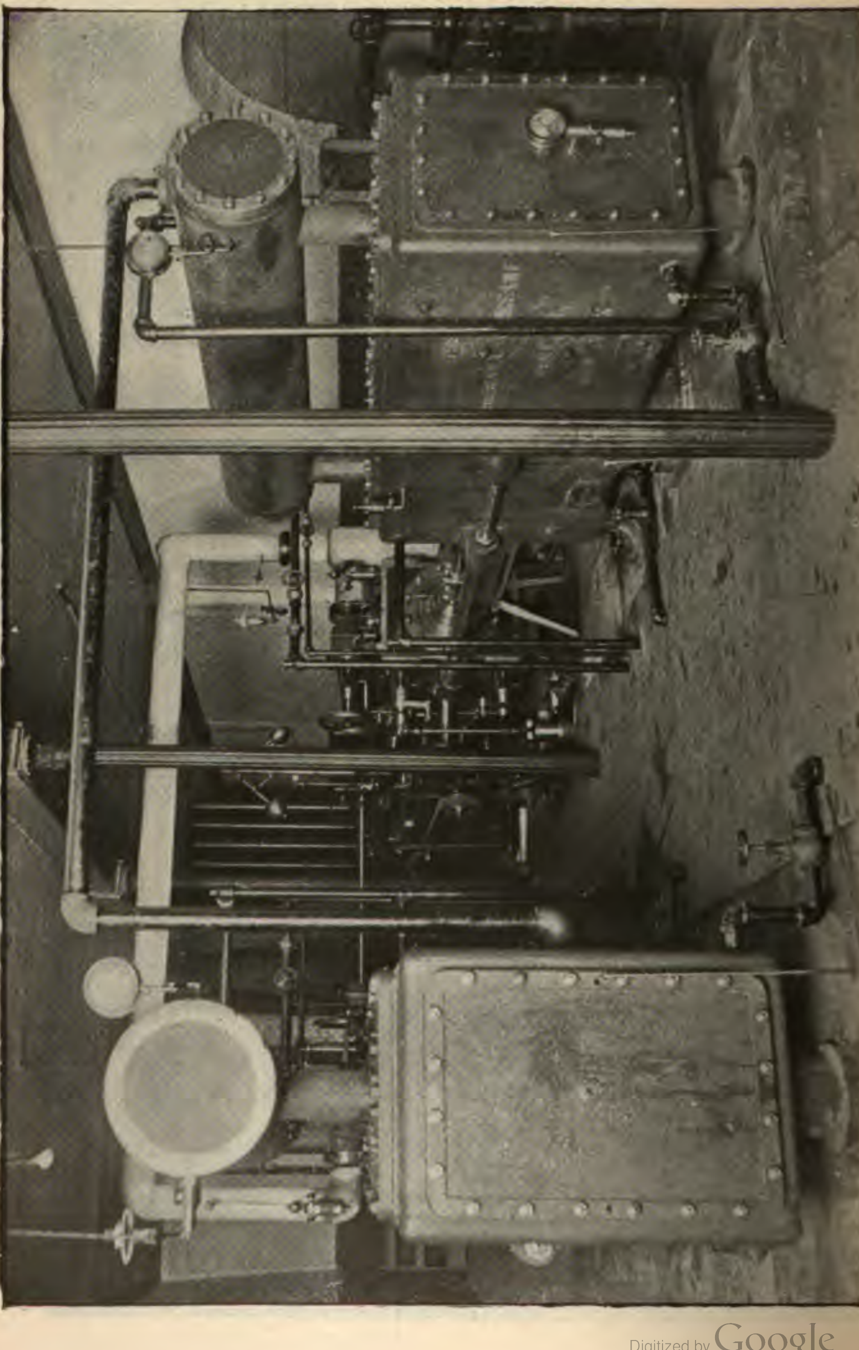

FIG. 218. Ingersoll-Sergeant Four Stage Air Compressor—Air End. Compressing to 2,500 Pounds Gauge Pressure.

designed by Mr. Henry C. Sergeant, and compressing air to 2,500 pounds per square inch.

This machine, which is illustrated in Figs. 217 and 218, was built for the American Air Power Co., and designed to furnish compressed air to the Hardie Compressed Air Locomotive which was tried experimentally on the Manhattan Elevated Railroad in New York.

The air compressor is operated by a duplex non-condensing Corliss steam engine, having steam cylinders 18 inches diameter

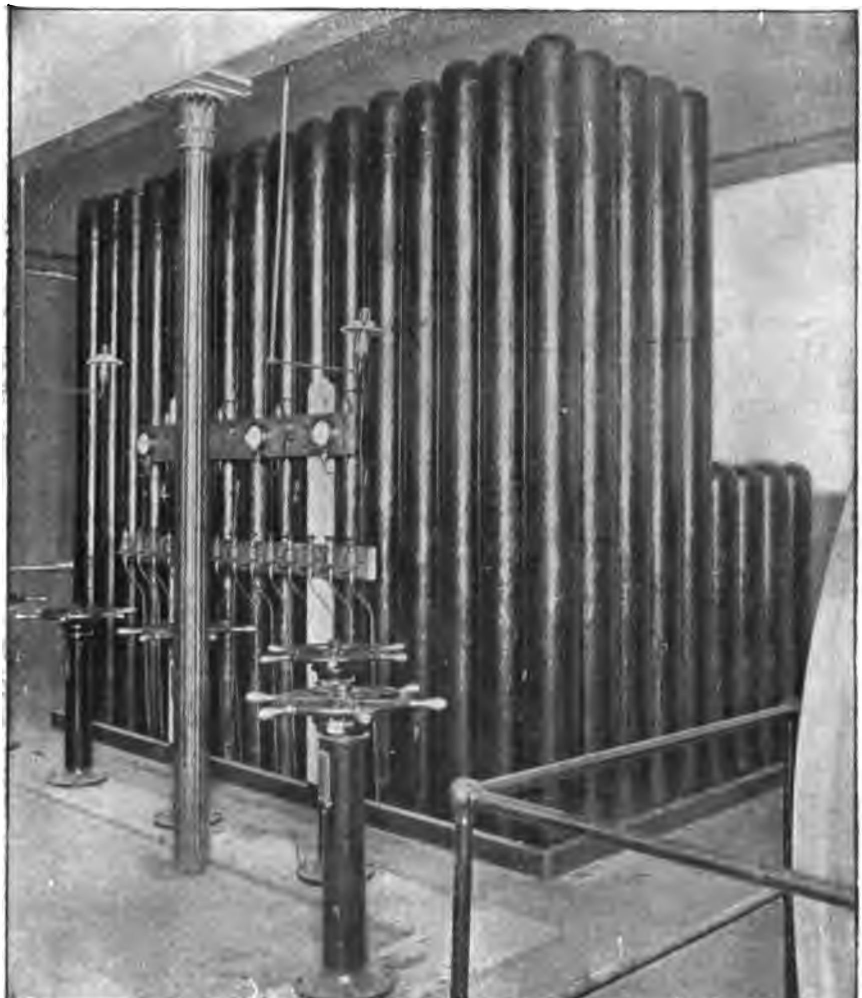

Fig. 219. High-Pressure Air Reservoir, for Air at 2,500 Pounds Gauge Pressure.

by 36 inches stroke, and all parts of heavier construction than is usual for a machine of this size. The piston rods of the steam cylinders are prolonged through the back heads and connected with the air-cylinder piston-rods by clamp couplings.

The air end of the machine, shown in Fig. 218, consists of four single acting air cylinders, having a stroke of 36 inches and of the following diameters:

Low Pressure or Intake Cylinder..........	21¼	inches.
First Intermediate Cylinder................	9	"
Second Intermediate Cylinder.............	7	"
High Pressure Cylinder..................	3	"

The cooling system used is very complete. The low pressure and first intermediate air-cylinders are placed tandem, as are also the second intermediate and the high pressure cylinders, and each pair of cylinders is completely enclosed in a rectangular water-box through which water circulates. After each compression the air passes through an intercooler which serves to abstract most of the heat of compression. There are three (3) intercoolers, and an after-cooler takes the air from the high pressure cylinder and reduces its temperature to that of the intake air.

A very interesting test of this compressor was recently made and very fully described in *Engineering News* for October 7, 1897. The record of this test shows the following temperatures and pressures during the passage of the air through the successive stages of compression:

The temperature of the intake air, which enters the low pressure cylinder through a piston inlet valve, registered 78.5 degrees F. On leaving the low pressure cylinder the pressure was 60 pounds and the temperature 194 degrees, which the first intercooler reduced to 98 degrees. The first intermediate cylinder carried the compression to 126 pounds and the temperature to 162 degrees. The second intermediate registered a pressure of 665 pounds. The temperature of the air on leaving the high pressure cylinder at 2,500 pounds gauge pressure stood but 214 degrees, which was reduced to 79 in the aftercooler.

The storage tank to which the air passes from the high pressure cylinder is illustrated in Fig. 219. It consists of 144 Mannesmann tubes, nine inches diameter and one-third inch thick, having a total capacity, including connecting pipes, of about 925 cubic feet. These tubes are connected up in four sets or batteries, each one equal to the storage capacity of the tank on the locomotive.

An illustration of the Hardie Compressed Air Locomotive is shown in Fig. 220, and a detailed description may be found in the issue of *Engineering News* for June 24, 1897. This machine was built by the American Air Power Co., to demonstrate the feasibility of using it in place of the steam locomotive on the Manhattan Elevated Railroad, and several very successful trial runs have been made over the elevated tracks.

FIG. 220. The Hardie Compressed Air Locomotive.

The business of the Ingersoll-Sergeant Drill Co. dates from the introduction of the Percussive Rock Drill in operations of mining, tunnelling and quarrying. At first compressed air was not employed except on underground work where it was impossible to use steam, and not until the commencement of the Chicago Drainage Canal was it used on surface work to any considerable extent. Here the slide valve compressors first installed were of the same type previously employed by the contractors in driving tunnels, and consumed probably 50 pounds of steam per horse-power per hour. Later installations were of the Duplex Corliss type, which soon showed such a marked fuel saving that even with coal costing but $1.60 per ton, the reduction in operating expenses was considerable, and the larger first cost of the high duty machines was soon found by the contractors to be a very profitable investment. Since then the tendency has been towards still greater fuel economy, and a recent order which the company now have under construction for the contractors of the Jerome Park Reservoir, New York, will have for the steam end a Cross Compound Condensing Corliss engine, requiring about 15 pounds of steam per horse-power per hour. The air end will also be compounded, with an intercooler of the receiver type placed between the high and low pressure cylinders, and effecting an additional saving of fully 10 per cent.

A comparison between this type of compressor and the machines first employed on the canal about five years ago shows a marked advance, and it also shows a decrease in fuel consumption of more than 70 per cent.

Recent developments in compressed air have shown many new uses to which it may be applied, and some applications, although not entirely new, are now given a more extended field of operation.

One of these is spray painting, the use of which is rapidly extending for structural and general engineering work. The first use of compressed air in this capacity was on the World's Fair buildings. Since then it has gradually come into use, first on railroad work, for painting cars and buildings and whitewashing interiors of shops, and more recently, for general exterior work, both new and old.

In using air for the painting of old structural or bridge work, and the hulls of vessels, the sand blast is first employed to thoroughly clean the surfaces to be covered. The sand blast removes every particle of old paint and scale and leaves a perfectly clean surface to receive the paint. For such work the painting machines have an auxiliary air jet, which is first opened and all the dust blown off the surface before the paint is put on.

Recently, in New York City, the iron work of the United States Appraiser's stores, a ten-story building covering a whole block, was painted by compressed air. Here one man with a spraying machine covered as much surface in four minutes as could be done by hand in forty minutes.

The gas holders of the Equitable Gas Co., Fortieth street and Avenue A, in New York, have just been painted by this process. The painting was done from the ground while the holders were gradually raised, the holders being employed for the storage of gas during the operation. Three men, using two sprays, covered 16,000 square feet in seven hours at a cost for labor of $6.25, or less than ½c. per square yard. The amount of paint used was about the same as by hand work, which is ordinarily done at the rate of about 1,200 square feet of surface covered per day by one man.

The terminal of the Manhattan Elevated R. R., at 155th street, New York, is located directly under the viaduct which extends from Washington Heights across the Harlem river. The smoke and gases arising from the locomotives rapidly destroy the paint on the latter structure, exposing the metal to the action of the weather. In five years the viaduct has received four coats of paint, and is now being cleaned and painted by compressed air with the expectation of securing by this process a more durable coating.

In preparing the structure for painting a simple air jet was first employed, and it is said that some tons of scale were removed by this means before any sand was used. For the sand blast two 9/16" cast iron nozzles are used, each consuming about 200 cubic feet of free air per minute at a pressure of about 20 pounds. With two nozzles 700 to 800 square feet of surface are cleaned and painted per day, the first part of the day, up to 3 o'clock

in the afternoon, being consumed in cleaning, the remainder in painting.

Compressed air has been used for many years for conveying through pneumatic tubes messages and small packages between stations usually located in the same building; but recently has been successfully installed on a much larger scale in New York city and Philadelphia.

The New York line runs from the postoffice to the Produce Exchange, a distance of about 4,000 feet. The tube consists of cast iron pipes, made and laid like water pipes, but bored out true, forming a continuous tube 8⅛″ in diameter. The carriers are 24″ long and 7″ in diameter, each holding 600 to 800 letters, and making the trip of nearly four-fifths of a mile in about two minutes.

The new air compressor which is now under construction for this plant will be of the Duplex Corliss type, with steam cylinders 14 inches in diameter, air cylinders 26¼ inches in diameter by 18 inches stroke, and will maintain an air pressure of about twelve pounds.

New fields are rapidly opening to compressed air, and the air compressor is found in the most unexpected places. In mining and manufacturing, in medicine and the arts, compressed air is used. On engineering work it has accomplished much and will do more. To compressed air and the percussive rock drill is due a large measure of the success of such gigantic achievements as the New York Aqueduct Tunnel, driven through nearly thirty miles of solid rock, and the Chicago Main Drainage Channel with its fifteen miles of channeled rock walls and 12,000,000 cubic yards of rock excavation.

XIX.

STEEL FORGINGS.

(A Discussion had October 6, 1897, in connection with the Society's visit to the Bethlehem Iron Works, on its "Excursion to the East" in September, 1897.)

Mr. H. F. J. Porter: Mr. President, your good fellow-member, Mr. Reynolds, has relegated me to the outskirts by calling me a stranger here tonight, which position I want to take exception to; but inasmuch as I am considered a stranger, I want to say a word from that standpoint.

I want to say that the Bethlehem Iron Company were very glad to see such a very representative body of men down at their works last week. They thought that Chicago had done herself proud in sending such a body of men to represent her.

Now, I had the pleasure of reading a paper before the Western Society of Engineers last fall on the subject of Steel Forgings, etc., and I then opened up the interior of our works as well as I could by means of lantern slides; and last week, when they were at our works, I was a little sorry to find that my talk had made so little impression on some of the members that they asked me a great many questions that showed that they had neither heard nor read the paper; or, at all events, if they were present on the occasion of its reading, either I did not make myself understood to them or else I succeeded only in putting them to sleep.

Mr. Rohrer: I would like to ask Mr. Porter in regard to the hydraulic pressure per square inch in the large press at the works.

Mr. Porter: The hydraulic pressure per square inch is seven thousand pounds. I do not know the exact area of the two plungers of the press, but the total capacity of the press is fourteen thousand tons, which is developed when the fifteen thousand horse-power engine is running with one hundred and fifty pounds of steam pressure and eighty revolutions per minute.

President Johnston: That is the absolute pressure brought to bear on any metal that happens to be under the press?

Mr. Porter: Yes.

President Johnston: One question that I intended asking at the mill was, as to the size of the armor plate that was being forged at the time that we were at the works.

Mr. Porter: I did not take notice of that at the time; I did not know just what they were going to put under the press and I did not ask at the time what the size was. I think it weighed between thirty and forty tons.*

*This plate was for the turret of the cruiser "Kearsarge." It was 11 ft. 2 in. long, 9 ft. 10 in. wide and 15 in. thick and weighed about fifty tons.

Mr. Reynolds: **What is the thickness of some of the** armor plate?

Mr. Porter: We have made plates twenty inches thick, a great many eighteen inches thick.

President Johnston: Is that class of work done any more by the use of the hammer, or has the hammer been abandoned entirely?

Mr. Porter: The hammer is being rapidly abandoned. Krupp I know has put in presses, but there are one or two armor plate manufacturers in Europe who have not given it up altogether.

President Johnston: How long has it been since abandoning the hammer at Bethlehem?

Mr. Porter: It has not been used for about four years.

A Member: How long can you work on a large piece of metal without reheating?

Mr. Porter: That depends on the size of the piece of metal we are forging. We must keep it up to a certain temperature, about eighteen hundred degrees, at least, and below that we must reheat it.

Mr. Snow: How long would that armor .plate that we saw, weighing about thirty tons, hold its heat?

Mr. Porter: I think it would hold its heat over an hour. The work of forging keeps up its heat.

Mr. Bley: How long is the head of the die in contact with the metal of the plate at one time?

Mr. Porter: I should think a second, perhaps a little more.

Mr. Bley: How long does the edge of the die stand up? Does it crumble very fast?

Mr. Porter: Not that I know of.

Mr. Snow: How are the plates fastened to the backing? I noticed that the edges were all lapped, and a man going over them with an emery stone.

Mr. Porter: There are bolt holes tapped into the back of the plates and tap bolts are screwed into them. These pass through the backing, and then there is a large nut which goes on the back of that. I think there were bolts in some of the plates that you saw.

A Member: I would like to ask Mr. Porter, if I can do so with propriety, what is the chief item of the increased cost of the government work that is turned out; that is, I mean to say, is it on account of the rigid inspection and throwing out of defective plates?

Mr. Porter: Well, in the first place, armor plate being made of nickel steel, the metal itself is expensive. Then, again, nickel steel in its working requires the greatest care. It requires the highest skilled labor and the largest and most powerful tools that we have in our works to handle the large masses of very tough metal. The very large press, for instance, which you saw working on a piece of armor plate, costs considerable money, as you may imagine, per hour to operate, and the cost

runs about the same on all the tools for that kind of work. There is a great deal of hand labor on it also, because in certain stages no tools have been invented that will do the necessary work on it. Then it takes a week, and sometimes two weeks, to heat up one of those big masses of armor plate, as the heat has to be applied gradually, and it happens occasionally that after spending months on a piece of armor plate we find, when about finished, that there is a crack in the plate and it has to be rejected. Then the harveyizing process is expensive. Every time you heat such large masses of metal it takes a vast amount of fuel; the general expense chargeable to this department is very large. If we could have a contract for armor plate that would keep our armor plate department busy the year around, just like a shoe factory, turning out our armor plate as people do shoes, we could reduce our price enormously. But if we have a plant that will get out ten thousand tons of armor plate per year, and only get an order for two thousand tons it is like having a great big shoe factory capable of making ten thousand pairs of shoes and turning out only two thousand pairs, and when we charge up the expense against the two thousand pairs of shoes, each becomes expensive.

President Johnston: If there are no further questions to ask Mr. Porter in this connection, I would ask him if there is anything occurs to him in addition to the matters in the paper read last October. I am sure we would be glad to hear it.

Mr. Porter: I have been asked by quite a number of your members regarding the method of making hollow forgings, as to whether they were cast hollow or not, and there seems to be a good deal of uncertainty on that point.

Ingots from which hollow forgings are made are cast solid. The object of doing this is to take care of two defects, viz., segregation and piping. These defects are described at some length in my paper, last fall*. They occur in that part of the ingot that cools last. By casting the ingot solid we make the center the part that cools last and collects the defects there. Then we bore it out. After it is bored, as you saw in a hollow forging that was being made, it is reheated and a steel mandrel put through the hole and then the press is used to forge it out on the mandrel.

Mr. Condron: I noticed outside of the works a hollow forging which I think had an internal diameter of thirty inches, as I remember it, possibly larger. Now I do not know whether it was a gun jacket or what it was; quite a large mass, like a piece of pipe. Was that made in the same way that you speak of?

Mr. Porter: That was a gun jacket, and it was made in very much the same way, except that instead of keeping the anvil block under the work it is removed and the mandrel is supported at each end on horses and thus becomes an internal anvil. The hole is thus enlarged and the metal is expanded into a ring. You probably noticed a very large ring that was on a car out in the

*See page 718. Vol. I, No. 6.

yard, about eleven feet in diameter, and five inches thick. That was a field ring for one of the Westinghouse generators at Niagara Falls and was made in this way.†

Mr. Condron: How do you get the mandrel out of a forging?

Mr. Porter: That is really a matter of skill with the forgeman.

A Member: We noticed that on a shaft that was being forged, they took the mandrel right out without any trouble.

Mr. Reynolds: Do they ever, in rolling hollow forgings, have a mandrel involved between two rolls, one roll inside?

Mr. Porter: Yes, tires are made on the principle that you speak of.

President Johnston: The tooling out of those large rings for the Niagara water power is an example of making a pipe of very short length, but one of very large diameter, a very heavy one.

Mr. Porter: There are one or two things that I would like to speak of. There is a very strong impression abroad that the work as turned out by the Bethlehem Iron Company is very costly. Now, generally speaking, it is a little higher priced than similar work in the market. When purchasing agents, who are merely instructed to order forgings, ask for bids on them, we will say for a shaft or a connecting rod or piston rod, or something of that kind, they will find that the prices quoted by the Bethlehem Iron Company are higher, unless the specifications are so drawn that all the forges who bid on them would bid on the same basis. At our works we have a great many inspectors from large machine shops, from private consulting engineers, from the army and navy departments of the government. We have adopted a standard of work to meet the requirements which these inspectors are there to see carried out. Certain rules, demanded by best practice, are followed. For instance, it is customary for us, when a forging is ordered, to make it from an ingot at least twice its diameter. I should not say "at least," because sometimes it is a little less. If you want, we will say, a twenty-six-inch shaft, as ingots do not come exactly twice that diameter, we could not adhere exactly to our rule. They do, however, come fifty inches in diameter, and that is the size of ingot we would use. Now, unless a man who is in the market for a twenty-six-inch shaft should specify that the ingot from which that shaft is made should be at least fifty inches in diameter, or approximately twice the diameter of the shaft, we would bid the higher price because other forges have no presses and there is not a hammer in this country could turn it out properly. Let me give you an instance. On my way west I stopped over at Pittsburg to visit a large engine works there. We had bid only a couple of months ago on eight steel shafts twenty-six inches in diameter for engines that they were building, and I wanted to see the shaft. I think our price on those shafts was in the neighborhood of 3½ cents per pound, possibly a little less. They were bought elsewhere for 2½ cents per pound. I

†See Illustration page 733, Vol. I, No. 6.

subsequently stopped at the forge that turned out those shafts. I asked the foreman what his custom was in making his forgings, as to the size of the ingot that he worked them down from, and he said that "they varied," and that was all the information I could get from him on that score. His large hammer had a capacity for ten tons; the cylinder was eighteen inches in diameter and forty-two inches stroke. I asked him to measure the distance from the under side of the hammer head, which was raised to its limit and the top of the anvil block, and it was just forty-two inches. They could not possibly have put a fifty-inch ingot under their hammer, and yet they made those eight twenty-six-inch shafts. They must have been made from small ingots, and if so, the metal could not have been worked sufficiently to make good forgings; at all events, the hammer was entirely too light to affect the central metal of forgings of the size of these shafts.

Let me refer you to a recorded case which will show exactly what happens under conditions such as I have named. If you will refer to the government report of the tests of metals at the Watertown Arsenal for 1885, you will find on pages 944 et seq. the records of the tests made on the broken shaft of the U. S. Cruiser "Dolphin." This shaft was made of steel from a thirty-inch ingot under a ten-ton hammer, the cylinder of which was thirty-six inches in diameter and eight feet stroke. The following diagram was made by Prof. J. B. Johnson of Washington University, St. Louis:

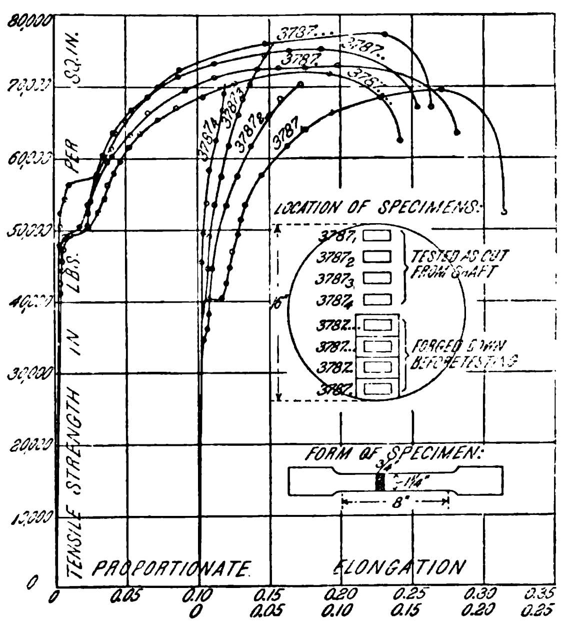

FIG. 221.

Test specimens were taken out of the metal at various distances between the surface and the center. Specimens 3787_1—$_2$—$_3$ and $_4$ were taken. The form of the specimens is shown. The tests are graphically shown in the curves. The test piece 3787_1, nearest the surface, showed an elongation of 21.4 per cent, and a contraction of 32.8 per cent; 3787_2 showed an elongation of 7.2 per cent and a contraction of 5.5 per cent; 3787_3 showed an elongation of 4.9 per cent, practically 5 per cent, and a contraction of 5.2 per cent; and the one nearest the center showed an elongation of 2 per cent and a contraction of 1 per cent. In other words, the elongation varied between the surface and the center from 21.5 per cent to 2 per cent, and the contraction varied from 33 per cent to 1 per cent. You can see, therefore, that the center metal in this forging was practically unworked. In order to be certain that there was nothing in the metal itself that would give this difference, they cut out from the opposite side specimens of a larger size and forged them down until they were of the same size of the first. In other words, they put work into the metal that ought to have been put into it when it was first forged, and as a result an average of 25 per cent elongation and 55 per cent contraction was obtained.

Here is another instance of the same kind of work. A gentleman who belongs to your Technical Club here visited our works a short time ago. He was only recently connected with one of the largest steel plants in the country, and he told me that the Illinois Steel Company had asked for prices on three plate bending rolls. I think they were about eighteen inches in diameter. We bid on them, and the other representative forges bid on them, and one of them got the order. There are no other forges than ours that make their own steel, and the forge that secured the order ordered the ingots for these rolls from the steel mill that this man is connected with and he told me that they returned one of the ingots, saying that it was "under-size" three-eighths of an inch. He told them that it was not unusual to have ingots vary three-eighths of an inch in diameter, that is, three-sixteenths on a side, that steel could vary that much simply from shrinkage. The purchasing agent gave himself away by writing back that in this instance the ingot would not "turn up!" In other words, the ingots were simply rough turned and sold as forgings. He found out that there was no forging done on them except at the necks or the bearings at each end, which were quite small.

There is another point that I would like to speak of. Yesterday I was at some of the large engine works at Milwaukee. They told me that the shafts which they generally bought in the market were not annealed—that they did not require them to be annealed. Now you know that if a shaft is not annealed, it has forging strains and strains due to irregular cooling and uneven heating remaining in it. They told me that it was customary for them, on account of these residual strains in their shafts, to rough turn them, then to cut the key-ways, and finally finish them. The

reason they can not cut the key-ways after the shafts are finished turned is, that when a key-way is cut, the fiber strains at that point are released, which allows the shaft to spring to such an extent as to be too crooked for use. Every shaft that we forge is carefully annealed and will not spring. The molecules of the metal then adjust themselves to a condition of rest and they are true from the time they leave our works until they have had some great stress put on them from outside, sufficient to bend them. Now shafts that have been submitted to this extra work, and which are absolutely perfect, as near as human ingenuity can make them, will cost a little more than those which are made as I tell you some people make them. I do not like to run down our competitors. I have to state the reasons for our prices being a little above those of forges which are turning out work that they are not properly equipped for.

There is one other thing that I would like to speak of. We not long ago sent to Watertown Arsenal a series of bars of steel, to be tested for fatigue of metal. The records of these tests are in the last issue of the government reports of the Watertown Arsenal. We have recommended that for shafts and moving parts of machinery that are apt to be affected by stresses alternating from compression to tension, or from either stress, to its absolute release, where fatigue of metal so-called, is what acts to destroy the piece eventually, that a high carbon steel should be used, and our recommendations are based on the result of experience, and these tests at Watertown confirm it. Forgings will fail, either from some defect due to manufacture or from fatigue of metal. These "fatigue tests" were made in this way. The bars, thirty-six inches long, one inch in diameter, are clamped at one end in a chuck, in a lathe, with the other end resting on a bearing. In the center, a lever runs across the bar, and a weight at the outer end of the lever presses it down so that the bar is slightly bent. Then the bar is revolved at a speed of fifteen hundred turns a minute until it breaks. Thus we have an actual case of rupture from fatigue. The bars that had .24 carbon, when simply annealed, broke at 230,000 revolutions; when oil-tempered, at 350,000 revolutions; the .46 carbon broke, when annealed, at 975,000; when oil-tempered, 1,700,000. The .66 carbon broke at 3,700,000, and when oil-tempered at 4,225,000, so that by a little more than doubling the carbon in the steel you more than twenty times increased its capacity to resist fatigue. The conditions under which these tests are made are similar to those affecting engine shafts, and to a certain extent they are the same in connecting rods and piston rods that are subjeted to alternating compression and tension.

The general custom in machine shops is to use a low carbon steel (of about .10 to .25 per cent carbon), for the reason that machine tools are not many of them calculated to work the higher carbon steel. This latter metal is very tough, and if it is worked like soft steel the tools break or the metal is torn all to pieces. If it is properly worked with a very fine cut and a high

speed, the headway is comparatively slow. Under either condition, therefore, the cost of using high carbon steel is more expensive. But if the engineer wants to get the best, he ought to specify that sort of material, and not get what it is to the interest of the machine shop to give him.

A Member: I would like to ask a question about that experiment with different grades of carbon. Was the power changed to agree to the different elastic limit in each case?

Mr. Porter: The weight was changed.

Mr. Condron: That interests me, because of some similar tests that I had my attention called to in stay-bolt fastenings. That is, the action that the stay-bolt is subjected to in a locomotive boiler. To carry on these tests they had a machine for making what they called vibration tests, and they have tested a great many different kinds of stay-bolts and, although I cannot repeat the figures, still the experiments are right along in that line that I have stated. One end of the stay-bolt is fastened to a fixed plate, and by a kind of cam motion the other end is joggled up and down. The bolts are subjected to a vibration of only 500 a minute, and the highest results that they have obtained, I think, are less than 100,000 vibrations on each stay-bolt. Now it seems to me as if there is quite a point to be raised with reference to steel for stay-bolts, and I would like to have some suggestions in regard to the use of nickel steel for stay-bolts. There is more than one firm considering the manufacturing of stay-bolts with nickel steel. I do not know whether nickel would have any strengthening property of that kind or not.

Mr. Porter: Nickel increases very perceptibly the elastic limit, just as carbon does, and if there were no other circumstances affecting the stress on the piece, I think that nickel steel would be very good for the purpose, but it is found that heat has a very disappointing effect, you may call it, on nickel steel. Oil-tempered nickel steel does not give as good results as simply annealed nickel steel, and in cases like this, where stay-bolts would be used, it is just possible that this effect of heating and cooling the stay-bolts alternately might very seriously affect nickel steel. They are only beginning to use nickel steel for boiler plates, and it has not been used long enough to satisfactorily recommend it. It has been used in a few boilers, but I have not heard of its getting into general use. I think it is only being experimented with.

Mr. Condron: Do you use aluminum in using steel castings?

Mr. Porter: It is used. We do not use it at all.

I also wish to say that some of the engineers about the country are specifying a pretty high grade of steel for forgings in the commercial engines that they buy. The engineers of the Boston Metropolitan Water Board have just called for bids on three 35,000,000 gallon pumping engines. They have only asked three or four of the pumping engine builders to bid. The specifications call for all the forgings to be of either fluid compressed or crucible steel. That throws the order either to our-

selves or Krupp. Then the elastic limit is required to be not less than fifty thousand pounds, and the elongation eighteen per cent in specimens ten inches long and one inch in diameter. That compels us to use nickel steel, so that we have to bid on fluid compressed nickel steel against Krupp's crucible steel.

There are specifications just about to be issued at Cincinnati for three 30,000,000 gallons pumping engines, and the specifications are very nearly the same as these, only the terms are a little different. They call for an ultimate strength of not more than 80,000 and not less than 70,000 pounds, with an elongation of twenty per cent in test pieces, of half a square inch in section and twelve diameters in length. That also requires nickel steel, and the forgings are all specified to be hydraulic forged.

Your fellow-member, Mr. Ericson, now your city engineer, has recently specified that the two pumping engines for your city, one of 30,000,000 gallons, and the other of 14,000,000 gallons capacity, shall be supplied with steel forgings, hydraulic forged and carefully annealed. Your fellow-member, Mr. Potis, chief engineer of the North and West Chicago street railways, has for several years supplied his power plants with hydraulic forged steel shafts, forged hollow on a mandrel. I could mention by name many other of your members who are fully alive to the improvement made in recent years in methods of manufacturing forgings, but I fear I have occupied more of your time tonight than you bargained for when you asked me to make a few remarks.

XX.

GLIDING EXPERIMENTS.

An Address* by Octave Chanute, C. E., Mem. W. S. E.

Delivered 20th of October, 1897.

Mr. Chanute stated in beginning that when, in 1891, Professor Langley, the eminent astronomer, and the secretary of the Smithsonian Institution, published his important work, "Experiments in Aerodynamics," the closing paragraph of the summary was as follows: "I wish, however, to put on record my belief, that the time has come for these questions (i. e., those of aerodynamics and aerial navigation) to engage the serious attention not only of engineers, but of all interested in the possibly near practical solution of a problem, one of the most important in its consequences of any which has ever presented itself in mechanics; for this solution, it is here shown, cannot longer be considered beyond our capacity to reach."

Mr. Chanute continued that it did not seem to the general public then, and it possibly might not seem now, as if a commercial and practical flying machine was an achievement to be expected in the near future; yet it did seem opportune for an engineer approaching the end of his professional career to devote some of his leisure to the investigation of the laws which must be hereafter observed by other engineers in compassing the navigation of the air. He therefore took up the question; and believing that the surest method is first to study past failures in a novel undertaking, he made an investigation of the records of all the experiments, which had been tried during the last two or three hundred years, in the endeavor to imitate the birds. This resulted in a number of technical articles which swelled into a book, in which the attempt was made to eliminate the causes of each failure; for up to that time there had been nothing but failures.

He said he had hitherto abstained from addressing his fellow engineers on the subject, as some might deem it premature, but he had become gradually convinced, not only through investigation but through practical experiment, that it was not only possible but almost certain that man will eventually be enabled to make his way through and on the air by dynamic means, although it might require a considerable and long process of evolution to do so. This evolution was now in progress, and very great advance has recently been accomplished. It chanced that about the year 1888, a number of able men, in various parts of the world, simultaneously took up the question, and the progress

*Illustrated by lantern slides.

which they have made is already greater than that previously achieved during the past two or three centuries. Those men were Mr. Maxim, an American in England, Professor Langley in this country, Mr. Hargrave in New South Wales, and Mr. Lilienthal in Germany. They investigated afresh the laws which underlie the possible solution of the problem of flight, and the results of their labors will probably best appear from a discussion of the various elements of that problem.

These elements number ten at least, and may be considered as so many subsidiary problems, each to be solved separately, perhaps in more ways than one, and those solutions then to be combined into a harmonious whole. They may be stated as follows:

1st. THE SUPPORTING POWER AND RESISTANCE OF AIR.

This first problem is the foundation of the whole subject, and, singularly enough, it is only within the last six years that it has been settled beyond question what is the true measure of those properties of air when meeting a surface at an oblique angle of incidence. Sir Isaac Newton gave by implication from his proposition XXXIV, Book 2 of the Principia, a law which has variously been intrepreted as meaning that normal fluid pressures vary as the sine, or the square of the sine of oblique incidence. These formulae are today still taught in the schools, and found in text books, although experiments have shown that at very acute angles they give from one-tenth to one-twentieth of the true results. Engineers make current use of them in calculating pressures upon roofs, and upon parts of bridges struck obliquely by the wind, while with later knowledge it can be shown that a wind gust deflected upward under the floor of a bridge, even so little as 5 or 10 degrees, produces such a lifting effect as to account for the blowing off of superstructures hitherto accounted as inexplicable. In point of fact, Professor Langley's experiments showed that oblique air pressures varied not as the sine, or the square of the sine of incidence, but, approximately as indicated in the empirical formula proposed by Col. Duchemin about 1828, in which the relation between the rectangular normal pressure and the oblique normal pressure is represented by:

$$P = P' \times \frac{2 \text{ Sine } a}{1 + \text{Sine}^2 a}$$

In which P= the oblique pressure.
P' =The rectangular pressure.
a=The angle of incidence.

This applies exclusively to planes or flat surfaces, while Lilienthal has shown by experiment that curved surfaces presented with their concave side to the wind afford still greater pressures, these being from twelve times to four times the normal pressures obtaining upon planes at angles between 1 and 5 degrees, which are those most favorable for flight. Thus it is that we are now enabled to calculate with some confidence the support which

may be obtained by gliding at any given speed upon the air, and the power required to overcome the resistance. An eminent French mathematician, at the beginning of this century, calculated that a swallow, weighing six-tenths ounces, expended in full flight no less than one-thirteenth of a horse-power. This calculation was evidently erroneous. It would have implied that the weight of a man, say 150 pounds, would require the expenditure of something like 300 horse-power to sustain it in the air, but calculations of the power really required could not be made with confidence until the recent labors of Professor Langley, confirmed as they have been by those of Mr. Maxim, and the still more encouraging coefficients for concave surfaces obtained by Lilienthal and in the experiments which were to be presently described.

2d. The Motor, its Character and its Energy.

This second problem, now nearly solved, was thought until five years ago to be still more difficult than the obtaining of supporting power from the air. It was known that the motor muscles of birds, though possessing but little more tensile strength than those of land animals, gave out energy at a much more rapid rate, so that it was variously estimated that bird machinery (muscles) weighed from 5 to 20 pounds for one horse-power exerted. Upon investigation in 1890, it was found that the lightest steam engines then in use were those in launches and weighed 60 pounds per horse-power, that the lightest petroleum engines weighed 88 pounds per horse-power, while the lightest electric motor weighed 130 pounds, and the lightest storage battery and dynamo weighed some 200 pounds per horse-power hour. Since then the advance has been very great. Mr. Maxim has produced a steam-plant of 360 horse-power which weighs about 8 pounds per horse-power. Professor Langley has built an engine and boiler which weighs 7 pounds and exerts one horse-power, while Mr. Hargrave has constructed a steam engine weighing about 10 pounds to the horse-power. Almost as great advances have been accomplished with petroleum motors, which possess the great merit of dispensing with a boiler, so that for the first time the realization of a sufficiently light motor for a dynamic flying machine seems to be within sight. It now seems probable that this will be accomplished with a petroleum engine when the eccentricities now inherent to that class of unperfected motors have been overcome in practice.

3d. The Instrument for Obtaining Propulsion.

The third question relates to the device through which adequate thrust shall be obtained by action upon the air. All sorts of contrivances have been proposed; reaction jets of steam or of compressed air, the explosion of gunpowder or even nitro-glycerine, feathering paddle wheels of varied design, oscillating fins acting like the tails of fishes, flapping elastic wings like the pinions of birds, and the rotating screw. Mr. Maxim and Professor

Langley have made many experiments to determine the best form, speed and pitch of the screw to obtain thrust from the air, and have materially improved that instrument, which, to reason from analogy in land and water transportation, seems likely to prove the best device, but both Mr. Hargrave and Mr. Lilienthal have obtained very favorable results with the flapping pinion, which requires no intervening machinery to change the reciprocating action of a piston into a rotary motion, and it seems perhaps possible that success in artificial flight may be obtained with either or both devices.

4th. The Form and Kind of the Apparatus.

This fourth question has elicited great divergence of views among the designers of flying machines. Almost numberless projects have been advanced, but they can all be classified under three heads. 1st. Wings to sustain and propel. 2d. Rotating screws to lift and propel, and 3d, aeroplanes or aerocurves, to consist of fixed surfaces driven by some kind of propelling instrument. The first two have been the first to be proposed and experimented with. They have many warm advocates at the present time, but the practical experiments made within the last five years seem to indicate that success will first be achieved with aeroplanes, or to state it more accurately, by coining a new word, with *aerocurves*, which have been shown by Lilienthal to furnish much greater lifting reactions. The following table, in which the weight of the operator of a one-man machine is included with the weight of the apparatus, approximately indicates the comparative merit which our present knowledge enables us to assign theoretically to these three varieties of flying machines.

Comparative efficiency of various forms.

Kind of Apparatus.	Pounds probably sustained per Horse-power.	Proportion probably available for motor.	Resulting possible weight of motor per Horse-power.
Screws	25	17 per cent	4 lbs.
Wings	80	10 per cent	8 lbs.
Aerocurves	80	17 per cent	14 lbs.

It will be noticed that this involves motors which shall be very light in proportion to their output of energy, and that the fuel and other supplies must also be included in the weights above given, but yet that the desired results for aerocurves at least are now almost in sight.

5th. The Extent of the Sustaining Surfaces.

The fifth problem, relating to the extent of surface required to support the weight of a man, has caused in the past active controversy and gathering of data. It was perceived that in consequence of the law inherent to solids, the surfaces will increase as the squares, and the weights as the cubes of the homologous dimensions; it might well be that the additional relative weight due to the greater leverage should make it impossible to compass any larger flying machine than existing birds. Indeed, it is not so long ago that a distinguished scientist published an article in

which he flatly took the ground that an artificial flying machine was impossible for three reasons: 1. That Nature, with her utmost effort, had failed to produce a flying animal of more than fifty pounds in weight. 2. That the animal machine was far more effective than any that man may hope to make. 3. That the weight of any artificial flying machine could not be less, including fuel and engineer, than 300 or 400 pounds. These assertions have since been modified, but the author still holds that the possible limit of weight cannot be pushed much, if at all, beyond 100 pounds of machine and operator together.

In point of fact, flying creatures vary in extent of supporting surface from about 40 square feet to the pound in the butterfly, to an area of 44-100 square feet to the pound in the duck. The amount required depends upon the speed of the creature's flight, the larger soaring birds generally spreading about one square foot or less to the pound, while the experiments of Lilienthal, as well as those to be hereafter described, have demonstrated that a man's weight can be well sustained, at 22 to 25 miles an hour, by an apparatus spreading three-quarters of a square foot to the pound, and that this apparatus need not weigh more than from 23 to 36 pounds, without motor or propeller, so that if the latter weigh some 60 pounds more, we may fairly expect to compass a dynamic machine with a weight of about 100 pounds, carrying a man of about 150 pounds, upon sustaining surfaces of rather less than 200 square feet in area.

6th. The Material and Texture of the Apparatus.

The sixth question relates to the material to be selected for the framing of the machine, for the motor, and to the texture of the sustaining surfaces. Nature accomplishes her purposes with bone, flesh and feathers, but man has at his command metals, fuel and textile fabrics. Many hopes were expressed some years ago, when aluminum first became a commercial metal, that it was about to solve the problem of aerial navigation. Later investigations have developed the fact that aluminum is as yet inferior to steel per unit of weight. It is lighter, but it is also weaker. For a beginning wood will do very well. It is a fact, realized by few engineers, that the best woods, so long as they remain undecayed, are actually stronger in proportion to their weight than the ordinary grades of steel. Wood is easily and cheaply procured and shaped, and whatever success has hitherto been had in gliding flight has been accomplished with wooden frames covered with textile fabrics. The latter are probably inferior in efficiency to the ribbed surface of feathers, as quite recent experiments tend to show, but they will answer for a beginning.

Thus we see that six out of the ten subsidiary problems involved in the general question have been approximately solved. Not all, but most of this has been accomplished within the last few years. The remaining four problems are more difficult of solution, but even towards this, gratifying advance has been made.

7th. THE MAINTENANCE OF THE EQUILIBRIUM.

The seventh problem relates to the stability of the apparatus in the air, and especially in a wind. This equilibrium must be maintained at all angles of incidence and under all conditions of flight and of wind, in rising, in sailing and in coming down. The first requisite for this is that the center of gravity shall constantly be in a vertical line with the center of pressure, and unfortunately the latter is almost constantly varying with the relative wind, with the speed and with the angle of incidence. It is a peculiarity of air pressures, ascertained by experiment, that as the angle of incidence changes, the position of the resultant center of pressure also changes. When air meets a surface at right angles, the center of pressure coincides with the center of that surface, but when the angle becomes more acute, the center of pressure moves forward until it approaches a position about one-fifth of the distance back of the front edge on a plane. This movement is approximately expressed by what is known as Joessel's formula for square planes:

$$C = (0.2 + 0.3 \operatorname{Sin} \alpha) L.$$

In which $C =$ The distance from the front edge.
$L =$ The whole length fore and aft.
$\alpha =$ The angle of incidence.

This formula is found not to be accurate for oblong planes, and even not strictly true for square planes, but it is understood that recent experiments are likely to produce a more accurate formula for planes. The great need, however, is for a formula which shall accurately express the movements of the center of pressure on concavo-convex surfaces. They are known to present some curious anomalies, but no physicist, so far as is known, has yet reduced them to the reign of law. The problem of stability may be said to have been very considerably advanced. The experiments hereinafter to be described were undertaken with the sole view of evolving the solution of this question, for it is held to be of the very first importance. Far more so than seems to be realized by experimenters; for until automatic equilibrium is secured, and safety is ensured thereby, under all circumstances, it will be exceedingly dangerous to proceed to apply a motor and a propeller. Birds preserve their balance by instinct, by skill acquired through long evolution and tentative practice. Man will have to work out this problem thoroughly, even to the temporary disregard of the others, if he is ever to make his way safely upon the air.

8th. THE GUIDANCE IN ANY DESIRED DIRECTION.

The eighth problem relates to the steering. It has been generally supposed that this would be best effected by horizontal and vertical rudders, but the experiments of Lilienthal, and those to be here described, have shown that slight changes in the position of the center of gravity are more immediate and effective. This problem cannot be said to be fully worked out, but it is not

deemed to be very arduous. We already know that a gliding machine is exceedingly sensitive to the least change in the position of the weight or of the rudders, and therefore that it will be easily controlled by slight movements, if they are accurately made.

9th. The Starting up Under all Conditions.

The solution of the ninth question as to the best methods of starting away from the ground is likely to be one of the last to be practically worked out. It will require a great deal of experimenting and ingenuity to devise means for rising from a level under all conditions. This is a task for the future. Meanwhile it is easy by special appliances, or by starting from an eminence in the wind, to get a machine into the air so as to work out the more immediate problem of stability.

10th. The Alighting Safely Anywhere.

The tenth problem relates to the alighting. It is the one which always produces a smile upon its bare enunciation, probably in remembrance of that little experiment of Darius Green. It may be said to be as yet unsolved for the dynamic machine of the future, and yet, both Lilienthal's experiments and those to be now described showed this problem to be very easy of solution with a gliding machine, by simply making use of increased air resistance at greater angles of incidence to stop the headway before alighting on the ground.

Lilienthal probably accomplished more towards a practical solution of the general problem of flight than any of the previous experimenters. He was an accomplished engineer and mathematician, an ingenious inventor and a skillful experimenter. The first thing which required to be practically demonstrated was that a man's weight could be safely carried by gliding upon the air, and that he could alight safely. Lilienthal was the first man to produce these results and to reduce them to current practice. He made thousands of glides in safety, until the one dismal occasion in August, 1896, when a defect in his apparatus, probably the breaking of a wire, produced the fatal fall that deprived the world of his services and life. It is true that other men had safely descended in parachutes, that Mr. Maxim has made a short flight upon a dynamic machine, and that Mr. Hargrave has ascended a short distance under a team of kites, but Lilienthal was the first to demonstrate by repeated experiments that man could glide upon the air like a bird, and he will hereafter be recognized as the pioneer who indicated a method through which final success may eventually be won.

Continuing, Mr. Chanute said that when all the problems which he had indicated were solved--and it had been shown that many of them were partly if not wholly solved—they would still have to be combined into one harmonious design before a commercial flying machine was produced. It would therefore be conceived

that a good deal of experimenting will be required, and that such experiments will be fraught with danger. He had nevertheless advised in his writings, and in an article in the Engineering Magazine for April, 1896, that experiments be carried on preferably with full sized machines, carrying a man, as the more fruitful and instructive method. This was good advice, but it might prove dangerous for others to follow. He therefore deemed it desirable that he should ascertain himself how much of risk this involved, if made with due care and precaution.

It was not the intention, in these experiments, to seek to invent a flying machine, although that impression may have been conveyed by some of the newspaper notices of them. The intention was mainly to study the seventh problem—the maintenance of the equilibrium—which it was hoped to gain automatically. This it was expected to do by reversing the method of Lilienthal, who moved his bodily weight to bring back the center of gravity under the center of pressure, as fast as the latter shifted from any cause. It had occurred to Mr. Chanute that it might be preferable to provide moving mechanism within the apparatus itself, to shift the surfaces so as to bring back the varying center of pressure over a fixed center of gravity, and that in such case the operator need not move at all, except for the purpose of steering. The results have been exceedingly gratifying. Two forms of apparatus have been evolved, each equipped with a different device, which are now believed to be materially safer than any heretofore produced. With them several hundred flights have been made, extending over two seasons, without the slightest personal accident.

In December, 1895, Mr. Chanute secured the services of Mr. A. M. Herring, a civil and mechanical engineer, who had for some years been making experiments in Aviation, this being the recent name given to attempts to imitate the birds. The first thing done, after some groping with models, was to build a kite, in order to test the stability of the proposed gliding machine. This was called the "ladder kite," from its resemblance to a step-ladder in one of its postures, for it was so constructed as to admit of grouping its surfaces in various ways. This kite proved exceedingly stable, flying in gusty winds without the eccentricities common to that class of apparatus. Then the construction of a similar machine was begun, which was capable of carrying a man, but first Mr. Herring rebuilt a machine, previously tested by him in New York, somewhat similar to that of Lilienthal, so that the known should be tested before passing to the unknown. With these two machines Mr. Chanute and Mr. Herring, and two assistants (Mr. Avery and Mr. Butusov), went in June, 1896, to the desert sand dunes at the south end of Lake Michigan, north of Miller Station, about thirty miles from Chicago. The Lilienthal-like machine was the first tested.

FIG. 222. Modified Lilienthal Machine.

The Figure 222 represents Mr. Herring in the Lilienthal type of apparatus, poised in a wind at the top of a sand hill about thirty feet high, preparatory to making a glide. The machine spread 168 square feet of sustaining surface, was equipped with a double rudder, and weighed thirty-six pounds. With this about 100 glides were made, the longest being 116 feet. It proved from the outset an awkward machine to handle. Lilienthal, whose skill had been developed by four or five years of practice, obtained valuable and safe results with it, but it was otherwise with novices. Its operation involved a struggle with the wind before it could be brought under control, and this continued after the flight had begun.

In Fig. 223 this machine is shown gliding a short height over the ground. This was practiced to avoid untoward accidents, for the winds experimented in, of 12 to 17 miles per hour, constantly varied the position of the center of pressure so far and so rapidly through their fluctuations, that the operator had to shift his position as actively as a tight-rope dancer, but to greater distances, to avoid being overturned. The body had to be moved at times some 15 or 18 inches, and not infrequently in landing the apparatus was broken. This involved less personal risk than might be supposed, because the radiating ribs curve downward, as shown,

FIG. 223. Lilienthal Type Under Way.

so that they first come into contact with the ground when an awkward landing is made, and save the operator from harm. Similar experience seems to have obtained with an acrobat in a public garden in Vienna, with Professor Fitzgerald in Dublin, with Mr. Lamson in Maine, and with the *Journal* newspaper in New York, although Mr. Pilcher, in England, has succeeded well with a modified Lilienthal apparatus of his own building. At last, the machine shown on Figs. 222 and 223, after having been broken and mended a number of times, was finally discarded altogether, and within six weeks thereafter Lilienthal's sad death occurred while experimenting with his double-decked apparatus.

After abandoning this first form of machine, the experimenters in the sand dunes next tested the machine built after the fashion of the ladder kite which had proved so steady in the air.

Fig. 224 exhibits a front view of this arrangement. It consisted of six pairs of wings, superimposed and trussed together, pivoted at their roots upon a central frame, the lower chord of which was spread open to receive the man at the center. Here he was expected only to move for the purpose of steering, the stability to be maintained by the movements of the wings above him, which swung on their pivots back and forth, restrained by rubber springs, when the wind struck one side more than the other, or changed the center of pressure fore and aft. It will be seen that this is just the reverse of the first method tested, in which the man moved and the wings remained fixed. This wing movement took place as expected, but it was very soon found that there was an essential difference between the support from the wind derived from the same arrangement when flown as a kite, at an angle of incidence of 30 to 40 degrees, and when flown as a glid-

FIG. 224. First Form Multiple-Wing Machine.

ing machine, at an angle with the wind of three or four degrees, which is the most favorable for reducing the total resistance to a minimum. It was found that at very acute angles the moving air was deflected downward by the front wings, so that the support under all the following wings was greatly diminished, and that the apparatus was inefficient when its surface was considered. This had been expected, from prior experiments, and the frame had been designed so that the grouping of the wings could be readily changed. Then began an interesting and instructive evolution. The grouping of the wings was gradually changed, through six permutations, each being guided by gliding flights and by releasing bits of featherdown in front of the machine, and watching the paths of the air currents which swept past the wings. The result of this evolution was to change greatly the outward appearance of the apparatus while retaining the same general principle.

Fig. 225 shows the improved arrangement as seen from one side in flight. It will be noticed that no less than five of the six pairs of wings have been superimposed at the front, and trussed together. That the operator is within and under them, and that a single pair of wings remains at the rear to serve as a tail. This tail was flexible and vibrated up and down in flight when the angle of incidence varied in consequence of the back and forth movements of the pivoted front wings.

FIG. 225. Sixth Form Multiple-Wing Machine.

Fig. 226 shows a front view of the same machine in flight. About two hundred glides were made, in winds of 13 to 22 miles an hour, on a descending course of about 1 in 4 (14°), the longest flight being 82 feet from a height of about 20 feet. There was, however, undue friction in the wing pivots, thus retarding their

FIG. 226. Front View Multiple-Wing Machine in Flight.

automatic action, so that the operator had to move two or three inches, as against some 15 or 18 inches on the previous machine, and there being some further defects in the spacing of the wings, both vertically and horizontally, it was determined to rebuild the machine with the practical information thus obtained.

Camp was accordingly broken up early in July, with the conviction that more had been learned during this two weeks of experiment with full-sized machines than had previously been acquired during about seven years of theoretical study and experiments with models. The equipment was returned to Chicago, where three machines were constructed, and towards the end of August they were taken out to the wilderness of sand dunes, north of Dune Park, about five miles from Miller.

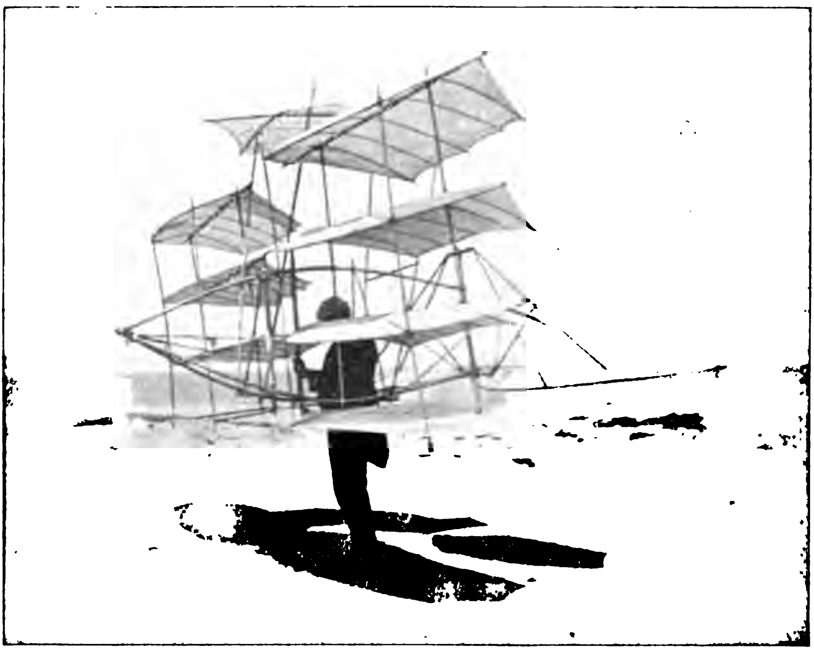

FIG. 227. Seventh Form Multiple-Wing Machine.

Fig. 227 shows the multiple-wing machine as reconstructed. This consisted of the same wings and of a new frame, and instead of ordinary pivots, there were ball bearings at the ends of vertical wooden posts to which the roots of the wings were attached, the latter being all trussed together, with vertical posts and diagonal wire ties, this being probably the first application which has been made of the Pratt truss to flying machine design. The frame was all made of spruce, the surfaces were of Japanese silk varnished with pyroxelene; the complete machine weighed 33½ pounds,

the supporting surface at the front was 143½ square feet, including a concave aerocurve over the top, added when the front wings were cut down to four pairs, and the rear wings or tail measured 29½ square feet in area. With this arrangement a great many glides were made, with the result of more than doubling the lengths previously attained, of reducing the angle of flight to 1 in 5, or 10° to 11°, and of diminishing the required movements of the operator to one or two inches in preserving the equilibrium.

FIG. 228. Multiple-Wing Machine in Flight.—(From a drawing.)

Fig. 228, reproduced from a drawing, shows this apparatus as it appeared in flight. It might have been preferable to omit the aerocurve over the top, and to have placed all the supporting surface in the pivoted wings at the front. This aerocurve was added to save the expense of rebuilding the old wings, and this saving proved to be a mistake. The wings were so far racked and distorted by their prior service that they did not support alike and did not balance the weight properly, and thus the results obtained with that machine were inferior to those to be hereafter described. Yet the principle is deemed to be sound, and it is believed that the apparatus can be further improved.

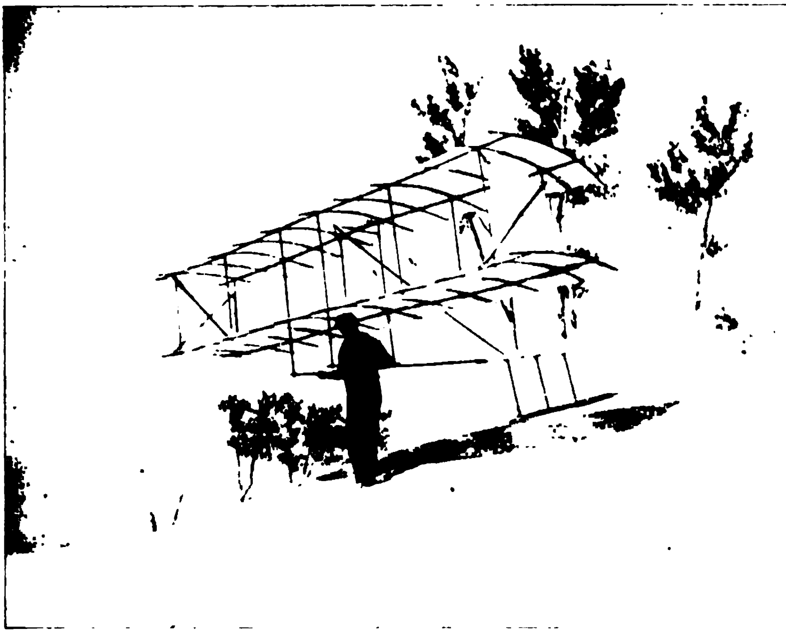

FIG. 229. Two-Surfaced Machine with Side Keels.

Fig. 229 exhibits the next full-sized machine which was built. It is seen to be very simple in construction, and to consist in a single intersection Pratt truss carrying the surfaces, to which was applied a regulating mechanism designed by Mr. Herring. This truss will safely support 300 or 400 pounds applied to the arm bars at the center. In calculating its proportions a basis has to be adopted which is the reverse of that which obtains in the calculation of bridges, for the support, or air pressure, has to be considered as uniformly distributed, and the load has to be figured out as concentrated at the center. It may be mentioned in this connection that one practical difficulty found has been in devising some method of adjustable connection between the vertical posts and the diagonal ties. The latter are from two to five hundredths of an inch in diameter, and it is not practicable either to cut a screw upon them for a nut, nor to apply a sleeve nut or a turnbuckle. Perhaps some engineer will suggest a better device than the loop heretofore used, which is made by twisting the wire back upon itself, and which is not adjustable.

With this apparatus as shown in Fig. 230, several hundred glides were made, varying in length from 150 to 360 feet, at angles of descent of 7½ to 10 degrees, and during the six weeks occupied with the experiments, not the slightest accident occurred either to the operators or to the machines. The regulating mechanism

FIG. 230. Two-Surfaced Machine Just Starting.

took care of the equilibrium fore and aft and diminished the effect of the side wind gusts which were then easily overcome by slight side movements of the operator. Towards the last amateurs were permitted to try it under instructions. They made fair glides in safety. One or two cruises by newspaper reporters, and another by a novice, who was picked up by the wind and raised some forty feet into the air, but who landed almost in his tracks as gently as if he had only fallen from the height of a chair.

Fig. 231 shows a side view of this apparatus in flight. On this occasion a glide was made of about 300 feet at a height of ten to twenty feet above the ground, but it was not uncommon for the machine to sail forty or fifty feet above the ground, and to pass over the heads of the spectators. The whole apparatus spread 134 square feet of supporting surface, weighed 23 pounds, and thoroughly supported the weight of a man at speeds of about 23 miles an hour. A piece of trestle work will be observed in the background. This was used to launch the machine which is next to be described.

Fig. 232 exhibits the fifth full-sized apparatus which was experimented with in 1896. It was the invention of a Russian, who claimed that he had already attained success in soaring flight with it, and as this closely resembled the machine of Captain Le Bris, who was said to have sailed with such a machine in France,

FIG. 231. Under Way and Level with the Starting Point.

in 1867, it was determined to give the design a trial. It was a somewhat complicated apparatus. Over the top was an aero-

FIG. 232. The Albatross Machine.

plane, below which two great wings extended, 40 feet across, and beneath which again there was a boat-like frame which could be transformed into a skiff by enclosing it with oiled canvas. The whole spread of supporting surface was 266 square feet and it weighed 190 pounds. As this could not, like the other machines, be carried about on a man's shoulders, special appliances were required to launch it.

FIG. 233. The Albatross on the Ways.

This appliance is exhibited by Fig. 233, and consisted of trestle work built down the slope of the hill. It involved the great disadvantage that it could only be used when the wind blew straight up the trestle, a rare occurrence. Nevertheless two launches were made, but in ballast, as there was no absolute certainty about the equilibrium. On the first occasion, with 130 pounds of ballast, it went off very well indeed, but did not sail very far. In alighting, some of the ribs of the boat-frame were cracked, but were replaced in an hour. On the second trial, with 90 pounds of ballast, but in a quartering, unfavorable wind, the latter swung the machine around, after it left the ways, and upon one of the wings striking a tree, the apparatus fell and was broken. On neither occasion would the operator have been hurt had he been in the machine, but it was evidently much too heavy and too

cumbrous to be successfully used in experiments designed solely to work out the problem of equilibrium.

This ended the experiments of 1896. A fuller account will be found in the "Aeronautical Annual" for 1897, edited by Mr. James Means, of Boston, whose publications during the last three years have done very much towards advancing the study and solution of the problem of Aviation. Detailed plans of the multiple-wing machine will be found in the 1897 issue.

The results of these experiments in 1896 were to develop two machines which are believed to be safer than any others previously tried. To advance materially the solution of the problem of equilibrium. To learn much about the management of flying apparatus in the wind, and to determine with some accuracy the power required. For this purpose the lengths and heights of some of the flights were measured. They were also timed, and it was found that the power expended was from 619 to 789 foot-pounds per second, or 1.13 to 1.43 horse-power to sustain 178 pounds in the air. This, however, was in a rising trend of wind. In nearly calm air, the power expended was found to be 2 horse-power, or at the rate of 89 pounds sustained per horse-power.

FIG. 234. Getting Ready.

This represented the actual thrust required to be exerted by a propeller. If we assume the latter to possess only an efficiency of 70 per cent, then we should require 2.85 actual horse-power on the shaft, and if the internal friction of the engine diminished its efficiency to 70 per cent of its indicated horse-power, then a motor of about five indicated horse-power might be expected to maintain an apparatus of the above type, carrying a man, in horizontal flight through the air. A result which is surely encouraging.

Mr. Chanute continued by saying that in 1897 he had inaugurated experiments with models for the purpose of testing still a third method of obtaining automatic equilibrium, but that these had not proceeded very far. That Mr. Herring, having been requested by an amateur to supply him with a gliding machine, had built a new one with his regulating mechanism, and that the pictures next to be shown had all been taken from flights made with that apparatus, it having been tested at Dune Park in September, 1897.

Fig. 234 exhibits the machine at the top of the hill, preparatory to making a glide. It is a common saying that a child must creep before he learns to walk, and something of the same required training obtains with a flying machine. The operator (Mr. Herring in this instance) is seen creeping under the machine in order

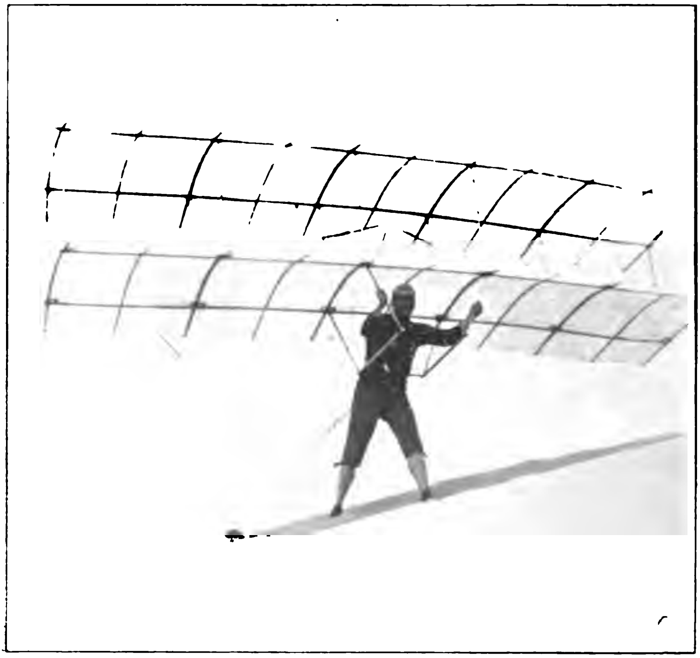

FIG. 235. Poised for Flight.

to rise with it, when lifted up by the two assistants, and to place himself within the arm bars.

Fig. 235 shows the apparatus poised in the wind. This involves generally a struggle with the breeze, which buffets the surfaces either from one side or the other, or fore and aft. A skillful operator resists this by bracing the machine against his back and keeping the front edge depressed, facing the wind accurately. As soon as this poise has been obtained, two or three running steps are taken, the front edge is slightly raised, and a leap is taken forward.

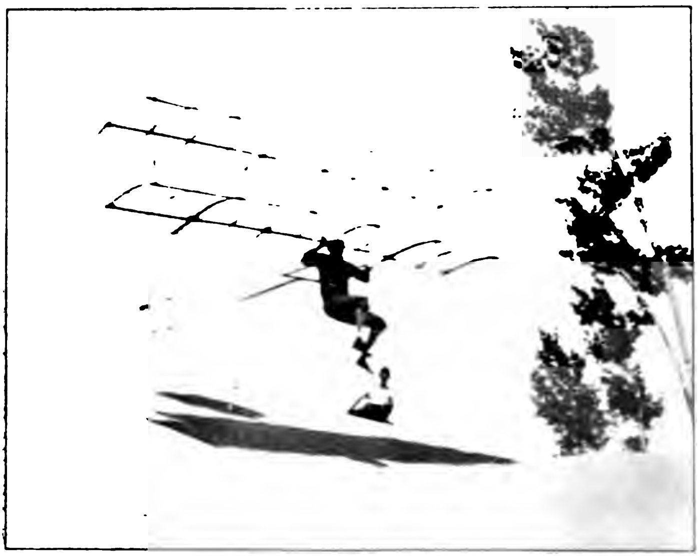

FIG. 236. The Flight Begun.

Fig. 236 shows the result, which is that the man is lifted up and supported by the air, and then sails forward at a slightly descending angle, the motive power being furnished by gravity, and the supporting power, which is due to the speed, being assisted by the adverse wind.

Fig. 237 exhibits the machine as thoroughly under way, the regulating mechanism providing for the fore and aft equilibrium, which is the most precarious and productive of accidents. If the wind be steady, and the operator has placed himself at just the right point within the arm bars, the glide might continue without any movement on the man's part, but there are incidents which are apt to occur in consequence of the irregularity of the wind, such as that shown in the next picture.

In Fig. 238, the apparatus is shown as struck by a side gust. The illustration in this particular picture was somewhat exagger-

FIG. 237. Well Up.

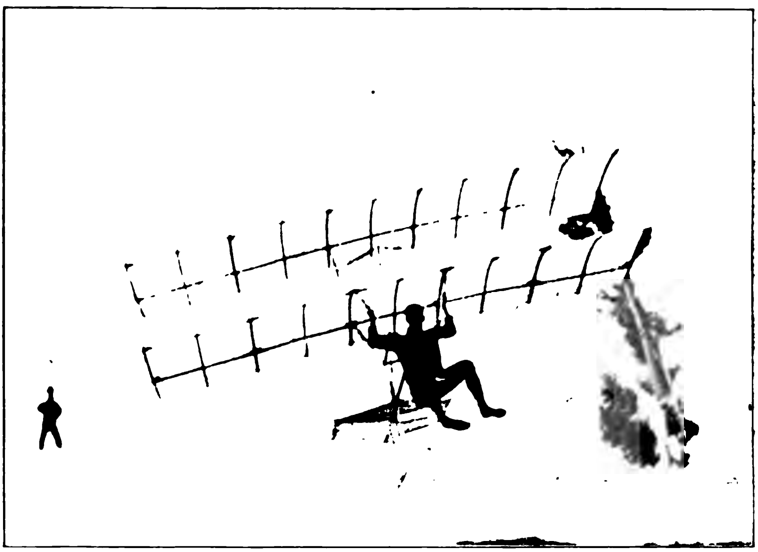

FIG. 238. Struck by a Side Gust.

ated by the fact that the camera was not held quite level, but it is clear that the left wing has been raised by the gust, and that

the operator has thrown his feet towards that side, in order to bring the wing down. It may be well here to remark that when in flight the bodily movements should be just the reverse of those which are instinctively made if standing on the ground. In the latter case, if one finds himself going over in one direction, the foot on that side is instinctively thrown out to that side; on a flying machine, if one wing is found to be depressed, the weight should be thrown to the opposite side in order to bring the wing down. This requires some practice to become second nature, but after awhile it is done semi-automatically, and without stopping to think.

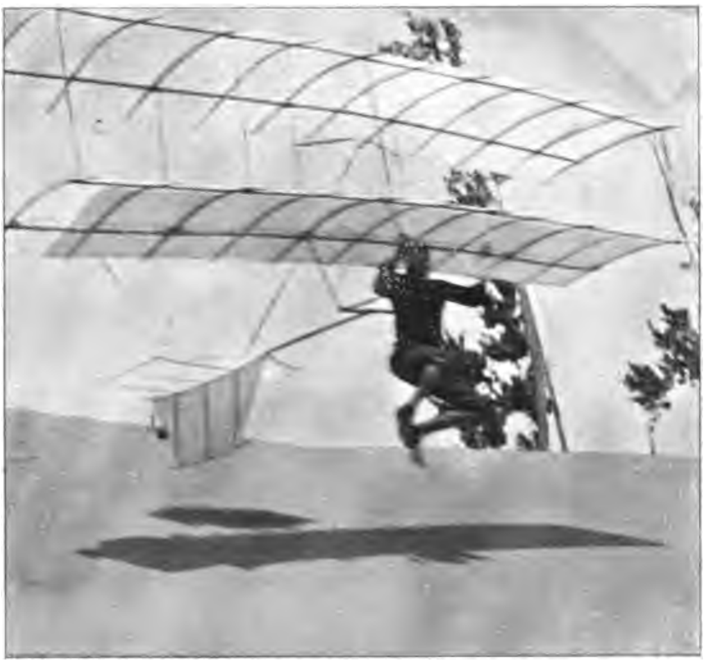

FIG. 239. Righted Again.

In Fig. 239 the machine has been righted up and is gliding forward on an even keel at a flatter angle of descent than the slope of the hill, so that the next picture shows increased height.

In Fig. 240 it is seen directly overhead of the camera and thoroughly under control, the legs having been raised up ready to be thrown in any direction to do the steering.

In Fig. 241 the trees have been passed for some distance, the apparatus is sailing steadily, and the ground is being gradually approached.

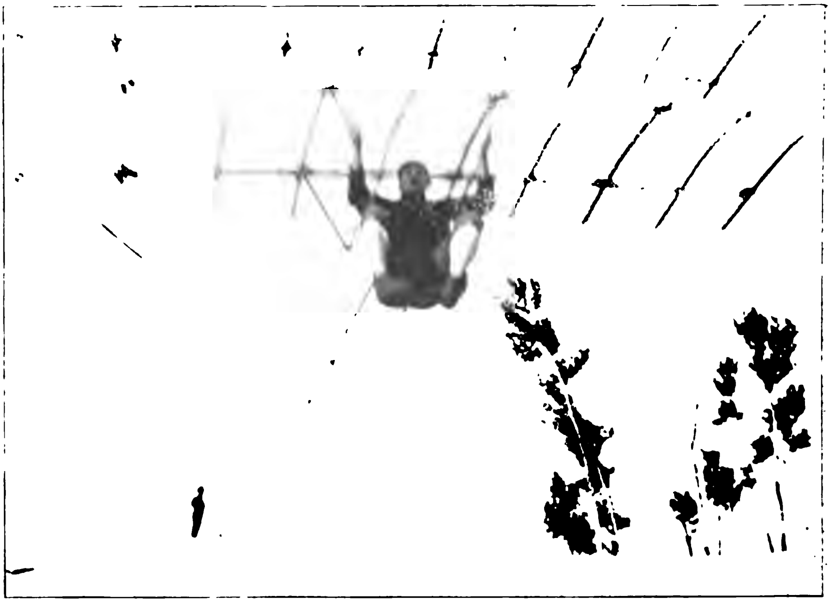

FIG. 240. Passing Overhead.

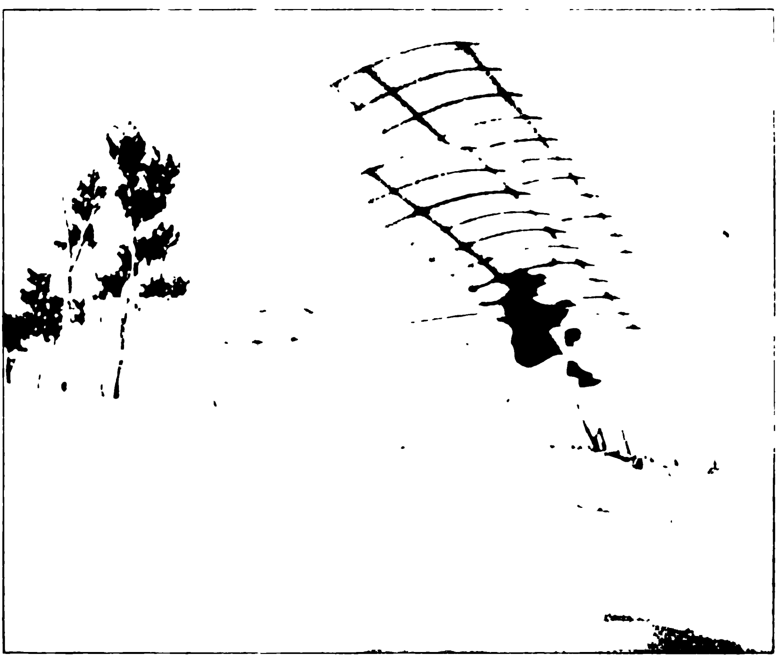

FIG. 241. Sailing Along.

In Fig. 242, the foot of the hill has been nearly reached, and it is time to think of alighting. This is very easily accomplished by pushing the weight of the body backward on the supporting bars, through a movement of the fore arms. The effect of this is to raise the front edge of the machine, thus increasing the angle of incidence and the consequent air pressure. This stops the speed, and as the diminished velocity also diminishes the pressure, the apparatus oscillates gently to a level keel, and the operator alights on the ground with almost no jar. The curi-

FIG. 242. Time to Think of Alighting.

ous in such matters will see this manœuvre performed thousands of times a day by the sparrows in the street. Mr. Herring and Mr. Avery, who were the experts who operated this machine at Dune Park, seldom or never struck the ground with greater force than would have been produced by jumping down one or two feet, and even when racing no sprained ankles occurred.

Fig. 243 shows the apparatus being carried back preparatory to making another glide. These were generally 200 or 300 feet long, and occupied 8 to 14 seconds, although it takes nearly 20 minutes to describe one of them. The sport is so exciting, the sensation of flying through the air is so delightful, that the operators immediately desire to make another glide, and they generally alternate in taking such flights. Each of the pictures shown has been taken from a different glide, but the effort has been made to have each represent a different phase, so that the sequence of aerial transit might be followed.

Mr. Chanute further said that the first requisite towards devising an artificial flying machine was to learn how such machines behaved in the air, and that he therefore advised constant practice to acquire the science of the birds. That the present auditors would doubtless like to know in greater detail just how it felt to

be riding on the air, and he therefore begged to introduce Mr. Herring, who would describe the remainder of the pictures.

Mr. Herring stated that the slides previously described by Mr. Chanute were views of flights taken toward what was known as the valley or southwest side of the hill. But those from view 23 onward were from the lake side or northern slope. Fig. 243, he

FIG. 243. Going Back Again.

said, represented very well the method of carrying the machine in mild or moderate winds, for in toiling up the slope the operator's feet sank so deeply in the fine yellow sand that outside aid was sometimes sought from the wind pressure on the surfaces. This pressure, which was a lifting one, amounted in some cases to more than 100 pounds, but that there were drawbacks to its use which required considerable practice of the carrier to overcome. These drawbacks, he said, were first, those due to the varying direction at which the wind arrived—each variation producing very wide range of travel of the center of lifting effort, and, consequently, considerable leverages to contend with—leverages so great that the 25 pounds weight of machine often became almost a negligible factor beside the forces which had to be occasionally contended with unless great care and quickness of action were exercised to always point the front of the apparatus into the momentary direction of the wind; the accurate judging of the extent of these momentary changes was a matter in itself which required considerable practice.

Another difficulty of handling the machine on the steep slope was, he said, due to a property peculiar to arched surfaces, namely,

FIG. 244. Near the Starting Point.

to a strong propelling component which they possessed at small *positive*, as well as negative,angles of inclination (to the horizontal), *when held in a strongly ascending* current of air, such as always existed in winds at the hillside. This propelling component,which tended to force the carrier back down the hill *against the wind*, would frequently be brought about by gusts, or disturbances in the wind which affected the vertical trend and produced these propelling components so suddenly and with such force, in winds of 20 miles an hour or over, that it was generally safer to employ two men to carry what in a calm would be a comparatively light load for one.

After arriving at the starting point, which, he said, was not at top of the hill but just a few feet beyond the position shown in the Figure 244, the apparatus was held with the chord of the surfaces pointed downward at a considerable negative angle in order that the machine should sustain only its own weight, and at the same time the apparatus was directed squarely into the momentary wind so that both sides lifted equally, and, while the machine was thus poised, the operator (in front of the apparatus), released his hold and slipped quickly underneath, passing his arms over the longitudinal bars (called arm bars), beneath the lower surface, at the same time grasping the front pair of diagonal struts which joined these bars to the framing. This done, the whole machine was lowered until the small cross-piece in the rear of the operator rested on his hips or the small of his back. In this position a considerable leverage could be exerted, and with practice even a novice could soon hold the machine under perfect control until the actual start was made down the hill.

Continuing, Mr. Herring said that in view of the small size of the machine, exposing in the present instance but 131 square feet of surface, one in first handling it would be surprised at the very great lifting effect, as well as the extent of the disturbing forces which come into play in comparatively light winds. He explained that this increased lifting effect was due to the very great superiority of arched surfaces over plane ones. This superiority had been first discovered and explained by the late Otto Lilienthal, a German engineer, who pointed out that the lifting forces which come into play were those due to a considerable thickness of air strata swinging around the arched profile of the surfaces—producing by their centrifugal moment (a partial vacuum on the upper or convex side of the surfaces and an added pressure on the lower or concave side—these together), giving lifting effects at small angles of inclination, such as from three to four degrees, (the same as used in flight on the present apparatus) equal to from eight to twelve times as much as could be produced by perfectly plane surfaces at the same angles and speed. It was common practice, Mr. Herring said, to designate all these machines as *aeroplanes*, although it was probable that if the inventor were limited to flat surfaces man-flight would not be possible with them, and, in view of the wide differences between the properties of plane and arched surfaces, Mr. Chanute and he used the word *aerocurve*, to designate the latter form. Continuing, the speaker said that on account of the internal irregularities which all winds possessed, it was a great deal more difficult to control any gliding machine on the ground than when the operator was in the air, and that this was especially true of the machines, that had been provided with the automatic regulating devices; on these, he said, the effect of the operator to keep the balance *proper*, while in flight, was, except in extreme cases, almost nil; but that when automatic regulation was absent or momentarily shut off, the flights, in winds of upwards of fifteen miles an hour, were marked by numerous movements of the operator requiring great quickness and considerable bodily strength which tired one almost as much as carrying the machine single handed up the hill. He said, to gather an idea of what those difficulties were which had to be contended with by either the operator or the mechanism, one might recall the actions of smoke issuing from a chimney which, if watched for any two succeeding fractions of a second, would show that its course was rarely the same, that in moderate or high winds it consisted of thousands of irregular curves and twists which came with a suddenness and irregularity greater than any man could intelligently follow, even mentally. He stated that their experiments had convinced them that similar disturbances existed throughout all winds, even the most steady, and that *as each of these changes or "gusts" had its disturbing effect on any apparatus depending for dynamic support on the air*, it was plain to be seen why Mr. Chanute had placed so much importance on the problem of securing automatic equilibrium, as the latter was,

undoubtedly, by far the most important of all the many difficulties connected with the whole subject. Consequently, nearly all of their recent experimental work had been directed to a study of these "gusts," or wind changes, and especially to the counteraction of their disturbing effects by automatic machinery. *For both felt convinced that without ample provision for automatically overcoming at least the more dangerous of these gusts a practical aerocurve, or aeroplane flying machine would be out of the question.* Mr. Herring said he felt himself to be too much of an enthusiast to express his own opinion of what had been accomplished by these experiments, but would leave it to others to form their opinions of the results, which, he said, were substantially as follows: That, whereas the maximum (natural) wind velocity in which an unregulated machine was ever controlled by an operator (Lilienthal) was in the neighborhood of 22 miles an hour, they had been able to experiment on the machine here shown in winds of 31½ miles an hour, corresponding to wind *energy* of about three times as great, with entire safety, and with another apparatus and more complex regulator this limit had been raised very much higher. Also, notwithstanding the fact that neither Mr. Avery nor the speaker, who operated the machines, possessed anywhere near the skill exhibited by Lilienthal, the latter's best flights had, nevertheless, been equaled if not exceeded.

He said that before describing the succeeding views, he wished to explain that, though he had stated that the exertion required in keeping the balance proper of the present machines was almost nil, he did not wish to convey the impression that movements of the operator's weight were therefore not resorted to. On the contrary, they were very necessary in directing both the course and the angle of descent, and that extreme sensitiveness of the machine to these movements of the operator was an essential feature to secure success with this type of apparatus, and that the ability to gauge these movements, as well as the speed and angle of the machine on the other hand, were the main points of skill required of the operator. Returning again to the views, he stated that after the machine was poised, as previously explained, the front edges were brought down until the chord of these surfaces pointed downward nearly parallel with the slope of the hill. In this position a running start was made towards the wind; the operator meantime advanced himself on the arm bars until he reached the proper position for flight, and as the speed increased, the apparatus gradually carried more and more of the operator's weight until he was entirely sustained. From this point the machine carried him the balance of the flight through the air, at a speed, and an angle of descent, dependent almost wholly upon his position on the apparatus. This speed varied all the way from 10 to 40 miles an hour in reference to the ground, or from 18 to 57 miles per hour in reference to the air, at the will of the aviator. A perfect guide, the speaker said, to the speed of the machine in reference to the air was furnished to the

operator, as well as to the spectators below, by the pitch of the note which the wires and framing made in passing through the air, a note similar to the shrieking of the shrouds of a ship in a storm.

The running start *in a calm* consisted of about half a dozen steps; *in moderate winds*, from two to three; and in *high winds* (those above 25 miles an hour), it was only necessary to give a slight positive inclination to the surfaces, when the machine and operator were raised high in the air, and then commenced their forward journey against the wind. The advance at a positive angle of inclination was due to the fact that arched surfaces possessed a strong propelling component, even at small *positive* inclinations (to the horizontal) *in strongly ascending* currents such as always existed on the windward slope of the hill. After reaching a certain point over the hillside (approximately one-third the way down the hill), a sudden decrease in support was generally experienced, due, in all probability, to a mass of slower moving air between the base and top of the hill, as measurement with the anemometer showed very much higher wind at the starting point and at the foot of the hill (or over the level stretch below) than between the two. The relationship in a 23-mile wind having been found to be as follows: Velocity at the lake, 20 miles per hour; at the foot of the hill (distant 300 feet), 16 miles; from first third to middle of the hill 9 miles per hour; starting point (one-third from top), 23 miles; and top, 23½ miles per hour. From which it would be seen that from starting in a wind of somewhat higher velocity than that necessary for support (21½ to 22 miles per hour), the machine (in the space of from one to one and a half seconds) passed into a wind capable of exerting but little more than one-sixth of that effect; the equilibrium, however,

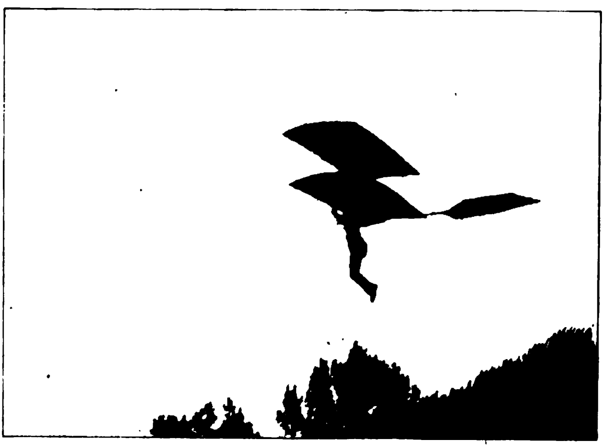

FIG. 245. Two Seconds After Start.

remained practically undisturbed; but to prevent losing headway, he said the operator should, in such a case, move his weight slightly to bring the surfaces at a greater negative angle than would be produced automatically by the regulating mechanism, as shown in Fig. 245, so that gravity might add to the speed during the descent and thus store a large part of the energy of the fall. After reaching the lowest point of this descent, which he said in some cases seemed to be attributable to a current of air curling backward against the mean wind, the operator again shifted his weight (or if he remained quiet the freshening wind would perform the same function through the regulating mechanism, but less quickly) and give the surfaces a slight positive angle as shown in Fig. 246, when by reason of the

FIG. 246. Four Seconds After Start.

increased speed of the machine and the fresher wind over the level stretch of the beach, the apparatus immediately rose, sometimes with greater rapidity than it fell, to almost the same level from which the descent was started, as shown in Fig. 247, the whole operation between Figs. 245 and 247 rarely occupying as much as three seconds. After passing the position shown in the last named figure, the flight as a whole was steady along a gradually descending line of one in six to one in seven, and occasionally but rarely one in eight. In strong winds, however, he continued, the gusts in the wind made considerable undulations in the flight, on a number of occasions raising the machine and operator as much as forty feet above the starting point, and giving the remainder of the course a number of vertical undulations departing from eight to fifteen feet from the mean line of the flights. The sensations produced by these sudden variations being somewhat similar to that experienced in a quick starting

FIG. 247. Five Seconds After Start.

elevator. One great peculiarity, he said, which distinguished the sensation of riding on the air from all other modes of locomotion was the exceeding smoothness and elasticity of the support, *and although ascending or descending motions were occasionally imparted to the machine, which were practically equal to what gravity would produce on a free moving body in the same time, yet, the application of these forces was always so elastic that there was never the slightest shock felt.*

FIG. 248. Nearly Down.

Continuing, he said the line of flight eventually approached nearer and nearer to the sand when it became necessary to select a proper landing point, and, at the same time, to head the machine directly into the wind, as was being done in Fig. 248, the landing in which case would be effected some sixty or seventy feet nearer the camera than the piece of charred wreckage in the foreground;the length of flight being on an average 268 feet horizontally in a descent of 42 feet in windy weather, or 254 feet in a calm from the same point, thus showing that in flights against the wind the ascending trend of the latter (blowing from the lake over the hill) furnished but little more energy than that necessary to overcome its own horizontal component and that the length of flight measured on the ground, in gliding against the wind, was

FIG. 249. Quartering.

more dependent upon the height from which the flight started than on the velocity of the wind.

Continuing, Mr. Herring said that so much had formerly been said relative to the necessity of starting and stopping against the wind that the impression had gone abroad that flight in any other direction with the present machines was impossible. He wished, therefore, to call attention to the Figs. 249, 250 and 251, which represented the machine facing north but advancing west of northwest in a wind coming from the northeast. These flights were known as quartering, in that they were made at an angle or "quartering" with the wind in order to make use of the ascending current over the slope which furnished in these flights *both support*

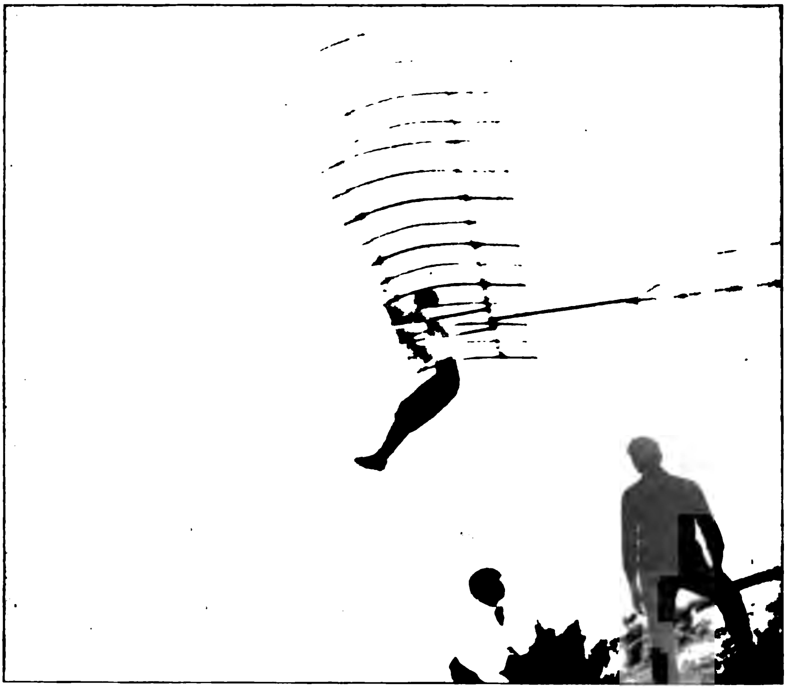

FIG. 250. Quartering Flight Overhead.

and propulsion. Such flights, he said, in a sufficiently strong wind, could, in a suitable locality, having a long hillside entirely free of obstructions, be prolonged indefinitely, but that his best attempt in this direction lasted only about 48 seconds. This, he said, was accomplished with a similar machine with three superimposed surfaces in covering a distance of 927 feet. There were, however, he said, few localities among the lakeside sand hills where this length of flight might be made except at the risk of running into trees or other obstructions, so that no matter how much longer than the average the level part of any particular flight might be there was still the same operation (that shown in Fig. 252) to be gone through with at the end, namely, the winding up of gravity's spring by man-power. This, said Mr. Herring, was a part of the operation which made one think more of adding the motor than any other. Whether the time were ripe for this step or not could, perhaps, be best judged by others; his individual opinion was, however, in the affirmative, and that, judging from the action of power-driven models of the gliding machine, which he had recently built and tested, it was probable, he said, that the power machinery would add to, rather than diminish the stability of the glider, and if this conclusion proved correct, the

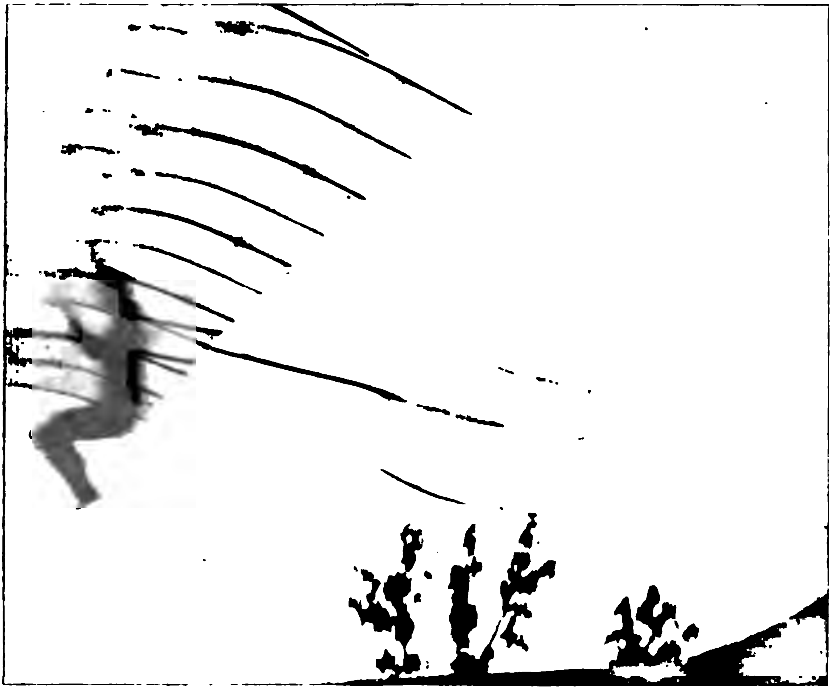

FIG. 251. Turning in Quartering Flight.

FIG. 252. Winding Up Gravity Spring.

finest mode of travel in the world, he thought, for the few, if not for the many, would not only be a possibility but a reasonable certainty of the near future.

President Johnston: I am sure we have all listened with a great deal of interest to Mr. Chanute's very interesting address and Mr. Herring's remarks, and if there are any others who have anything to say on this subject we will be glad to hear from them.

Mr. L. L. Summers: I would like to call attention to the fact that Mr. Chanute's modesty has prevented his calling attention to the particular work he has done. It is well known that Mr. Maxim, in England, has spent a small fortune in perfecting his machine, and his effort has been towards constructing a machine of full size, and I believe some $40,000 or $50,000 has been spent on it. He has never succeeded in actually flying, and he has broken his machine several times in getting away from the tracks. Mr. Chanute has endeavored in every way to avoid dangerous experiments and has confined his experiments to solving the problem of equilibrium. He has devoted a number of years to the subject, and I think all those who have read his book and know the great care he has taken to point out the success and failures of others, feel indebted to him. I think it is a source of congratulation to the West that we have an engineer and a scientist who is willing to devote himself to the subject in the way he has, and along the line he is working unquestionably must come our ultimate success. Many fail to appreciate that equilibrium must first be obtained before we can hope to accomplish successful flight, and to this problem Mr. Chanute's whole attention has been turned.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSLATIONS AND PERIODICALS.

"THE DIVERSION OF THE PERIYAR."

By John Pennycuick, C. S. I., Col. R. E.

(*Proceedings Institution Civil Engineers, Vol. CXXVIII, page 140.*)

From time immemorial the district of Madura has suffered from the want of water for irrigation. With the exception of a small area at its southwestern extremity, its geographical position prevents its receiving more than a scanty supply of rainfall. Almost all of this is utilized, either by means of storage in tanks or by channels leading from the Vaigai river, which drains the greater part of the district and receives the surplus from these tanks when filled. So thoroughly is the available rainfall utilized that it is only on very exceptional occasions, not more than once or twice in an average year, and in many years not at all, that any water is carried by the Vaigai to the sea.

In marked contrast to these conditions are those of the Travancore territory on the other side of the mountain chain which divides the watershed of the Arabian sea from that of the Bay of Bengal. Here the yearly rainfall is between 80 inches and 150 inches, giving perennial rivers, and a land of perpetual verdure. The Periyar river, which drains the portion of Travancore adjoining the southwest corner of Madura, flows for some distance within a few miles of the watershed ridge, its bed being less than 200 feet below the lowest openings in that ridge. It is not surprising that for many years a desire should have been felt to divert a portion of the superabundant supply of this river into the valley of the Vaigai for the benefit of the Madura district. The idea of thus diverting the waters of the Periyar is probably very ancient; but the first recorded expression of it dates from the beginning of the present century, when surveys were made for the purpose of ascertaining how far the proposal was a practical one. The result of these surveys, which appeared to have been made in a somewhat half-hearted manner, was to condemn the idea as impracticable; and, although it was repeatedly brought forward, it was not till sixty years later that the question was taken up in earnest by the late Major Ryves, R. E., who submitted the outline of a scheme sufficiently promising to justify the government of that day in ordering it to be worked out in greater detail.

The conduct of the necessary investigations was intrusted to the author, and the result was the submission to Government of a tolerably complete scheme for the diversion of the river. An

essential feature of this scheme was the closing of the existing river channel by an earthen dam about 200 feet high, it being supposed that the cost of a masonry dam would be so great as to be prohibitory. The Government, rightly in the author's opinion, considered that the risk of failure in an earthen dam of a height so greatly exceeding anything previously attemped was too great, and declined to sanction the scheme. The investigations already made serve, however, to show so clearly the enormous advantage to the Madura district which would accrue from the diversion of the Periyar that the subject was not allowed to drop; and when the author, a few years later, brought forward a proposal for the substitution of a masonary dam for the earthern bank formerly proposed, the suggestion was accepted. After much discussion, a complete scheme both for the diversion of the river and for the distribution of the water thus obtained was sanctioned for execution, and the necessary funds were provided.

The problems to be solved were: First, the closure of the existing river bed by a solid masonry dam; second, the provision, either by an open cutting or a tunnel, of means for the passage of the waters of the river through the mountain ridge separating the valley of the Vaigai from that of the Periyar; and, third, the construction of the works necessary for the distribution of the water thus obtained (amounting to some 30,000 million cubic feet annually) for irrigation in the Madura district.

It had originally been intended to make the relative levels of the dam and cutting, or tunnel, such as merely to divert the course of the river, without any provision for storage of water. But the later investigations had shown that this would not be enough, and that sufficient water must be stored between the sill of the cutting and that of the weir, by which surplus water was passed back into the Periyar valley, to overcome the fluctuations in the natural discharge of the river, and to allow a constant supply to be passed under complete control into the Madura district. The storage necessary for this purpose was calculated to be about 7,000 million cubic feet, and subject to this condition, the relative levels of the escape weir and of the sill of the cutting or tunnel would be fixed by considerations of convenience and economy. It was ultimately decided that the crest of the escape should be 144 feet above the datum ofthe Periyar surveys, at that time supposed to represent the mean level of the river bed at the site of the dam, the crest of the dam being 11 feet above this with the parapet 5 feet higher. It was calculated that with the length of weir available, the maximum depth of water passing over it would be 9 feet.

The passage of the water through the watershed ridge was designed to be effected by a cutting 21 feet wide with a slope of 1 in 440, leading to a tunnel with a cross-sectional area of 90 square feet, and a slope of 1 in 75. The length of the cutting was calculated at 5,400 feet, and that of the tunnel at 6,600 feet, a length which was considerably reduced in execution by a change

in alignment. The sill of the cutting, at its starting point, was 113 feet above datum; the contents of the lake between this level and that of the escape weir was calculated at 6,815 million cubic feet; that of the lake below the former level (which would, of course, not be available for irrigation), being 6,484 million cubic feet.

The valley at the site of the dam has a width of about 200 feet at datum level, and 1,300 feet at the level of the top of the dam. On each bank was a short saddle, formed by a depression between the hills immediately flanking the river, and a higher range farther from it It was proposed to use both these saddles as escapes, that on the right bank being cut down, and that on the left, which was considerably lower, being built up to the required level of 144 feet. The section to be adopted for the dam was the subject of considerable discussion, in which the author took a prominent part.

It was proposed to construct the dam entirely of concrete, the stone for which was to be obtained partly from the waste weir on the right bank, and partly from the watershed cutting. These intentions were slightly modified in execution, as it was found that the number of masons available was much larger than had been expected, and about one-third of the total contents of the dam was built of rubble. Difficulties of transport prevented more than a very small quantity of the stone from the cutting from being used, and separate quarries were opened for the supply of so much of the stone as could not be obtained from the waste weir—about a third of the whole. In order to construct the foundations of the main dam, it was proposed by the author to use temporary dams across the river, above and below, and by their means to divert the water into a tunnel driven through the solid rock on each flank. One of these (on the right bank) was also to be used for the supply of water to a turbine which would drive the greater part of the machinery required for stone breaking, concrete mixing, and other purposes. Either from an imperfect comprehension of what was intended, or from a want of acquaintance with what had actually been accomplished in other places, the professional advisers of the Government of India absolutely refused to consent to the construction of these tunnels, and their omission was made a condition of sanction to the execution of the project. Other means, which will be described later, were therefore adopted, which, though ultimately successful, were only rendered so by great labor and devotion on the part of the executive staff, and a heavy expense of both time and money. To this interference was due a large portion of the difficulties which attended the construction of the foundations of the main dam, and the whole of the annoying and expensive, though less important, interruptions to work which characterized the operations of all but the last two years. The estimates for the works were definitely sanctioned by the Secretary of State for India in 1884; but the Government of India, in spite of the urgent remonstrances

of the Madras government, refused to allot funds for their execution until near the end of 1887, when, somewhat unexpectedly, orders were issued for the immediate commencement of operations.

Before describing these operations in detail, it is necessary to describe briefly the peculiar climatic conditions of the Periyar valley, as these conditions had an important effect on the progress of the work. From the beginning of April to the end of June, jungle-fever is so prevalent and so deadly that engineering operations on any but the smallest scale are impossible. The number of workmen who could be induced to remain on the spot during these months was no more than enough for the maintenance of work already carried out, and both officers and subordinates had to be relieved at short intervals. The working year was thus reduced to the nine months from July to March; and of these months July, August, November and December were practically useless for work in the river bed on account of incessant floods, while all other work was impeded by continual rain. All work which depended upon coffer dams or temporary construction of any kind had therefore to be finished during the months of January, February and March; and all such work which was not complete and solid by the end of the last month would infallibly be destroyed during the following July. It should also be noted that the site of the dam was in an uninhabited jungle, 7 miles from the nearest point of a cart road, 20 miles from the nearest cultivated land, and 80 miles from the nearest railway station, which is 320 miles from Madras.

APPARATUS AND METHODS FOR TESTING PORTLAND CEMENT.

By M. Gary.

(*Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, 1896. Page 155. Abstract from Proceedings Institution Civil Engineers, Vol. CXXVIII, page 368.*)

In view of the revision of the "Standards for the Uniform Testing of Portland Cement," by order of the Prussian Ministry of Public Works, the Association of German Portland Cement Manufacturers has appointed a commission which has carried out some investigations in conjunction with the Royal Testing Laboratory at Berlin. The present paper describes the methods and apparatus in use at the Royal Laboratory, and suggestions for the improvement of the "Standards."

Time of Setting. The "Standards" specify "the cement shall be mixed with water (from 27 per cent to 30 per cent) to form a stiff paste from which a cake 1.5 centimetre thick shall be made. As soon as the cake is sufficiently hard to resist a slight pressure with the finger nail the cement shall be considered set. Slow-

setting cements shall be stirred for three minutes, quick-setting cements, one minute." In the Royal Laboratory all cements are at first stirred three minutes. If any cement begins to set in less time, it is stirred one-and-a-half minutes, since experience has shown that no workman, however skilled, can uniformly mix 300 grams or 400 grams (10 ozs. or 14 ozs.) of cement with water in one minute. The quantity of water used in mixing has a great influence on the time of setting. At the Royal Laboratory the cement is mixed with water until it can run off from the mixing knife in long thin threads like syrup. This consistency can be determined so closely that, with practice, a difference of 0.5 per cent of water can be observed. The quantity of water varies between 32 per cent and 38 per cent. To this mixture dry cement is gradually added, until it begins to collect in balls, when the pressure-test is applied. The Vicat needle apparatus for the accurate determination of the time of setting is described. The influence of temperature and the hygrometric state of the air on the time of setting are discussed, together with the corresponding precautions taken at the Royal Laboratory.

Constancy of Volume.—The "Standards" specify: "Portland cement shall preserve constancy of volume. A thin cake made on a flat glass plate, kept in moist air for twenty-four hours, then placed in water, shall afterwards show neither curvature nor cracks at the edges." Before immersion in water the thin cakes made at the Royal Laboratory are kept in a zinc-lined box, the lid of which has on its inner side thick felt, which can be kept moistened with water. The covering of the test-cakes with damp cloths is not recommended.

Fineness of Grinding.—"Portland cement shall be ground so fine that a sample shall leave behind not more than 10 per cent on a sieve of 900 meshes per square centimetre (5,800 meshes per square inch), the diameter of the wire being half the width of the mesh." At present it is impossible to obtain sieves to suit the requirements of the "Standards;" it would therefore be advantageous to order the sieve wire-gauze from one firm, so that uniformity may be attained. According to the "Standards," the width of mesh should be 0.222 millimetre, the diameter of the wire 0.111 millimetre. In the sieves used at the Royal Laboratory these dimensions are, respectively, 0.230 millimetre and 0.094 millimetre.

Strength Tests.—Test specimens, 5 square centimetres and 50 square centimetres, sectional area, respectively, for tension and compression, are prepared at the Royal Laboratory by means of five Bohme hammer-machines. Years of experience have shown that the objections raised in some quarters against machine-made test-specimens cannot be substantiated. The differences of the strengths of specimens prepared by the different hammers lie well within the allowable limits of error.

The arrangement of the mould, base-plate, and cover-box has great influence on the strength of the specimens produced. If the

mould lies loose on the table while the ramming is going on, the material gets pressed between the top of the mould and its cover-box. Dr. Goslich designed an arrangement for clamping mould, base-plate and cover-box firmly together; and later Prof. Martens designed an improved and simplified apparatus, which can be quickly worked and easily cleaned. Experiments show that specimens consisting of 1 part cement and 3 parts sand made in the new moulds are 2.5 per cent stronger in tension and 5 per cent stronger in compression than specimens made in the old moulds, and that greater uniformity is attained with a number of similar specimens. The manner in which the ram is guided through the cover-box has an influence on the strength of specimens. After a number of experiments, a ram going quite loosely through the cover-box has been adopted.

The calibration of the Michaelis lever tension-machine and of the Amsler-Laffon 30 ton press is duly described.

"To ensure uniformity of results, the sand used shall be clean quartz sand, washed and dried, and which shall pass through a sieve of 60 meshes per square centimetre (387 meshes per square inch), but be retained by a sieve of 120 meshes per square centimetre (774 meshes per square inch). The wires shall be 0.38 millimetre and 0.32 millimetre diameter respectively." The sieves obtained in the usual way from the makers do not at all satisfy the requirements of the "Standards." Two sieves at the Royal Laboratory, each nominally 120-mesh, contain 121 and 129 meshes per square centimetre respectively, and pass 35.4 per cent and 4.6 per cent of normal sand.

Preparation of Cement-sand Specimens.—The "Standards" specify a mixture of 250 grams cement, 750 grams sand, and 100 grams water. The Royal Laboratory find that in most cases 10 per cent of water, as specified by the "Standards," is too much, as some of the finer cement particles are washed away by the excess of water, and the strength of the specimen is thereby reduced. Formulas for the quantities of water to be used in different cases are given.

The paper is copiously illustrated by tables, drawings of apparatus, diagrams, and reproductions from photographs.

THE ACTUAL ACCURACY OF CHEMICAL ANALYSIS.

By F. P. Dewey, Washington, D. C.

(*Transactions of the American Inst. of Mining Engineers—Vol. XXVI, page 370.*)

The subject of this paper does not embrace the consideration of ways and means for the increase of analytical accuracy, or the question what could or should be attained in that direction. I desire simply to call attention to the degree of accuracy exhibited in actual every-day practice. In estimating this, little weight will

be given to the evidence afforded by the agreement of duplicate or multiple determinations by the same chemist; for I am convinced that such agreement is a delusion and a snare. Nor will special importance be attached to the agreement of two or even three analyses in special cases, or to the agreement between two methods practiced by the same analyst. I propose to compare the results obtained by several chemists working upon the same sample, and by various methods, in order to exhibit, as I have said, the actual condition of practice.

The available material for illustrating this phase of the question is unfortunately scanty; but something has been done, and I hope, by calling attention to some of the work in this line, to stimulate further work in the same direction by inducing others to prepare suitable samples and submit them to various chemists, who are competent and willing to make the necessary determinations and fully describe the methods they employ.

I draw most of my illustrations from the Transactions of the Institute, the Proceedings of the Association of Official Agricultural Chemists, and from personal experience.

Manganese in Steel.—In May, 1881, Mr. William Kent presented a paper to the Institute entitled "Manganese Determinations in Steel,"* in which he gave twenty-four determinations of manganese, made by ten different chemists, employing two main methods, on samples from a plate of steel. These results presented the remarkable range of from 1.14 per cent to 0.303 per cent, and one chemist reported results ranging from 1.14 per cent to 0.434 per cent.

A portion of this variation was undoubtedly due to variations in the samples, since the same sample was not used throughout by the different chemists.

Throwing out the anomalous result of 1.14 per cent, we have twenty-three determinations running from 0.619 to 0.303 with an average of 0.415 per cent, thus showing that at that time the determination of manganese in steel, when only about 0.4 per cent was probably present, might exhibit an extreme variation between the highest and lowest results of about 0.3 per cent, or 75 per cent of the amount of manganese present.

These results were certainly very discouraging, but if they did nothing else, they served to call attention to the very unsatisfactory character of the determination of manganese in steel at that time.

I do not recall any recent symposium on the determination of manganese in this class of material; but in 1880 Capt. A. E. Hunt,† in giving a measure of the accuracy of the calorimetric method, speaks of a variation of 0.02 per cent in steels containing 0.15 to 1.5 per cent of manganese as "sufficiently accurate for all practical work," thus clearly intimating that the current results of analysis by other methods were at least as good. This degree

*Trans. X, page 101.
†Trans. XV, page 104.

of accuracy, if attained by different chemists upon the same sample, must be considered a satisfactory advance over the results reported by Mr. Kent.

Early in 1883 Mr. G. C. Stone began a series of contributions on the "determination of manganese in spiegel."* In his first paper he reported 13 determinations by five chemists, all working upon the same "works"—sample showing from 15.49 to 13.83 per cent, and also 26 determinations by ten chemists, all working upon a sample of the same spiegel, prepared with especial care jointly by Mr. Stone and one of the other chemists, showing from 14.56 to 10.36 per cent. But some of the low results were obtained by experimental methods.

In the fall of 1883 Mr. Stone reported 20 additional determinations by five other chemists, ranging from 14.20 to 10.76 per cent, the extremes being reported by the same chemist when working by different methods, his favorite method giving from 13.84 to 13.65 per cent; the three low results (less than 11 per cent), were obtained by the Williams method. In this connection Mr. Stone presented an interesting table, dividing the methods used into four classes and the results into three classes, giving respectively, below 13, between 13 and 14, and above 14 per cent.

In the spring of 1884, Mr. Stone reported 27 new results, 19 by four new chemists and 8 by one previously reported, whose new results were obtained by several methods.

We have thus 73 determinations by 19 different chemists. Of these 2 are thrown out on account of the method used, and 11 "because the chemists were not entirely satisfied with them," leaving 60 determinations by 18 chemists, using 12 methods.

These 60 results range from 14.47 to 12.60 per cent and average 13.39 per cent. Leaving out 8 determinations by one method, which is considered to give low results, the lowest determination becomes 12.92 and the average 13.48 percent, showing an extreme variation of 1.55 per cent of manganese between the highest and lowest results, and showing only 44 per cent of the results within 0.2 per cent of the average.

In the discussion of Mr. Stone's second paper, Mr. J. B. Mackintosh† presented an analysis of Mr. Stone's first 46 results, retaining the results by the Williams method, from which he argued that the evidence pointed to 12.956 per cent as the true content of manganese in this spiegel. If this is the case, then there is a very decided tendency to get too high results in this class of work.

Taken as a whole, this investigation would seem to show that variations of 0.5 per cent in the determination of manganese in this grade (10 to 15 per cent Mn) of spiegel are to be expected, and much wider variations may be found.

Phosphorus in Pig-iron.—Early in the 80's Messrs. Potter and Riggs, of St. Louis, Mo., sent out a sample of pig-iron for the determination of phosphorus. This examination yielded 26 re-

*Trans. XI, page 323; XII, 295 and 514.
†Trans XI, page 300.

sults, by 11 chemists, using 5 methods, ranging from 0.181 to 0.141 and averaging 0.160 per cent, and showing an extreme variation of 0.040. The maximum variation reported by any one chemist was 0.017 per cent, while three reported duplicates agreeing to 0.001 per cent. These results have never been published. One of the chemists discovered arsenic in the sample, which would account for some of the variations in the series. His determinations, in duplicate, were 0.151 and 0.152 per cent.

In February, 1882, Mr. F. E. Bachman presented a paper to the Institute,* in which he reported 44 results by 18 chemists, using 4 methods, ranging from 0.165 to 0.096 and averaging 0.143 per cent. The extreme variation was 0.069 per cent. The maximum variation reported by any one chemist on straight duplicates was 0.01 and the minimum 0.0004 per cent. Experimental determinations by Mr. Bachman, using different processes, yielded variations amounting to 0.043 per cent.

At the Atlanta meeting in October, 1895, Mr. Geo. E. Thackray presented a paper entitled, "A Comparison of Recent Phosphorus Determinations in Steel."† He first gives a table of determinations of phosphorus by two chemists on 8 samples, the differences ranging from 0.033 to 0.012 per cent, one chemist uniformly getting high results. One found from 0.080 to 0.074 per cent, and the other 0.110 to 0.088 per cent in these steels. These results were manifestly unsatisfactory.

A second table shows results by three chemists, the buyers, the sellers and an arbitrator. By the arbitrator's determinations these steels carried from 0.087 to 0.063 per cent of phosphorus.

The maximum difference in any set of three results was 0.017 and the minimum 0.005 per cent.

These results were obtained in the settlement of sales. As a result of the discussion which accompanied the matter, two samples of steel were prepared and sent to various chemists. A fourth table gives 36 results obtained by 23 chemists, using 29 methods on one steel, showing results averaging 0.0496 and ranging from 0.055 to 0.045 per cent, an extreme variation of only 0.010 per cent. Any individual result was practically within 0.005 per cent of the average.

On the second sample 38 results are reported, averaging 0.0835 and ranging from 0.091 to 0.076 per cent, an extreme variation of 0.015 per cent.

My own results on these steels are not given, as they were not reported in time; but they add two more results by one more chemist in each case; and the results fall within the limits.

These results must be regarded as highly satisfactory, and show that here, at least, is one determination that can be made by many chemists working in many different ways, and yet with results agreeing very closely together. While it may not be necessary

*Trans. XXV, page 270.
†Trans. X, page 322.

to determine many things as closely as phosphorus in steel, yet it would be highly satisfactory if we could do so; and this is a good standard of excellence for us to aim at.

LIGHTHOUSE ILLUMINATION IN JAPAN.

By C. S. Du Riche Preller, M.A., Ph.D., A.M. Inst. C.E., M. Inst. E.E

(From Engineering, London, July 30, '97, page 128-9.)

The Japanese Government, which pays great attention to the lighting of its coasts, not long ago commissioned Messrs. Sautter, Harle & Co., of Paris, to supply the optical apparatus for a new lighthouse erected in the recently acquired Island of Formosa With characteristic foresight and intelligence, the Japanese lighthouse authorities resolved to adopt the lightning flash (Feux-Eclairs) system, which, as is well known, constitutes one of the achievements of the French Lighthouse Administration, under its present Director-General, M. Bourdelles, and has proved so successful on the French coasts that it is fast supplanting all the older lights, whether the illuminant be electricity, incandescent gas, or mineral oil.

It is not necessary to enlarge upon the principle of the lightning flash system here, since the writer dealt exhaustively with that subject in *Engineering*, 1893, Vol. lvi., No. 1437 *et seq.* ("The Electric Lighthouse of Cape de la Heve"), as well as in 1896, Vol. lxi., No. 1583, *et seq.* ("Coast and Lighthouse Illumination in France"). Suffice it, therefore, to state briefly the salient features of the new Japanese light, which is installed in one of those high iron towers, not unlike that of Roches Douvres lighthouse in the Channel, illustrated in *Engineering*, 1896, Vol. lxi., No. 1588. These towers are erected on the Japanese coasts in a remarkable manner, namely, without cranes or lifting machinery of any kind, but simply by bamboo scaffolding and inclined planes.

The optical apparatus of the Formosa light is of the first order, i. e., 920 millimetres or 36.2 in. in focal length, the illuminant being petroleum, having the specific gravity of 0.8, and its flashing point at 35 deg. Cent. The lamp is a six-wick burner, having a luminous intensity of about 500 standard candle, and consuming about 1.35 kilogrammes (3 lb.) of mineral oil per hour, or 5.4 tons per annum of 4,000 lighting hours. The height of the apparatus is 2.93 metres, or 9.6 feet. It is composed of three panels, and a spherical reflector in place of the fourth panel, each panel being composed of nine dioptric and 27 catadioptric elements, and embracing each an angle of 72 deg. The light diffused in the remaining angle of 144 deg. is collected by the reflector, and thence thrown back on the panels.

In accordance with the fundamental principle of the lightning flash system, the duration of the flashes emitted by the apparatus is only one-tenth of a second, that is, the time strictly necessary for a complete impression on the retina of the observer. The

flashes are emitted at the rate of one group of three flashes in each complete revolution of the apparatus, the interval of eclipse between two consecutive flashes being two seconds, and that between two consecutive groups, corresponding to the "dead" angle of 144 deg., being six seconds. To give this characteristic, the apparatus has to perform one complete revolution in the short space of 2+2+6=10 seconds, whereas first-order apparatus of the older type requires in some cases as much as 1.6 minutes, or ten times more.

So great a rotary speed as 10 seconds per revolution can, of course, only be obtained by means of the other essential principle of the lightning flash system, namely, by the apparatus rotating not on the antiquated traveling carriage with conical or spherical rollers, which would cause excessive friction, but by means of a floating drum which carries the table and panels of the apparatus, and is plunged in a mercury bath, the energy absorbed by the friction of the liquid surface being practically *nil*. The tank containing the mercury is supported by a hollow iron column, and the apparatus is centered on a pivot placed near the center of gravity. By this mode of suspension, which is that generally applied by Messrs. Sautter, Harle & Co. in all their lightning flash apparatus, the friction of the shaft on its bearings is entirely done away with, the actual friction being reduced to that of the pivot in its socket at the upper end, while the friction of the centering rollers on the rolling surface of the vertical column is *nil* when the apparatus is adjusted in a state of equilibrium. A further advantage of this mode of suspension is the ease with which the parts subjected to friction can be inspected; whereas in the case of a shaft revolving in bearings, inspection is necessarily much more troublesome.

The system of the apparatus rotating by means of a floating drum in a mercury bath admits further of governing the rotary speed by means of clockwork with counterpoise, instead of using more powerful but less suitable motors.

The photometrically tested intensity of the flashes of the Formosa first-order lightning flash oil light is equal to 154,000 standard candles, the luminous range being as much as 70 miles in clear, 32 in average and 14 miles in hazy weather. The range of 70 miles exceeds, of course, considerably the geographical range or direct visibility of the light, and applies, therefore, only to the glare or "sky illumination" produced by the flashes and visible beyond the horizon. The luminous range in hazy weather refers to a state of the atmosphere in which, in Japanese waters, the unit test light of one-tenth of a standard candle (1-100 of a *bec carcel*) is visible at a distance of three nautical miles, which practically corresponds to "hazy weather" in the Bay of Biscay, the atmospheric conditions of the two seas being, therefore, similar.* Indeed, the Formosa light is not unlike that of Hourtin

* The tested visibility of the unit light in hazy weather is, in the Channel, in the Bay of Biscay, and in the Mediterranean respectively, 2.45, 2.56, and 3.60 nautical miles.

(between the mouth of the Gironde and Biarritz), which is also a first-order lightning flash universal oil light, and gives, at intervals of five seconds, single flashes of 190,000 candle-power, one-tenth of a second in duration, the apparatus being composed of four complete panels without a reflector. (*Vide Engineering*, 1896, Vol. lxi., pages 802 and 803.)

A first-order apparatus of the old type, with slow rotation and long duration flashes, is composed of no less than 16 panels instead of three or four, and while burning the same amount of petroleum, the luminous power of its flashes is only 32,000 candles as against 154,000 and 190,000, viz., five and six times less. The lightning flash system has, therefore, made it possible to reduce the number of panels to one-fifth of that of the old type, and to give, at the same time, a five and six fold intensity of beam.

Equally conspicuous is the advantage of a first-order lightning flashlight like that of Formosa or Hourtin, or even of a third-order light of the same system like that of Porquerolles (Riviera) over hyper-radiant apparatus, e. g., that of Cape d'Antifer (between Fecamp and Havre), described and illustrated in *Engineering*, 1896, Vol. lxi., page 802, or that of Skroo (Fair Isle). These lights compare as follows:

		Focal Length.	Luminous Power.	Cost of Apparatus.	
		mm.	candles.	fr.	£
Skroo.........	Hyper-radiant..	1330	72,000		
Antifer†	" "	1330	160,000*	94,000	3760
Hourtin†......	Lightning flash.	920	190,000	40,000	1600
Formosa	" "	920	154,000	40,000	1600
Porquerolles† .	" "	500	72,000	25,000	1000

It is seen that the lightning flash apparatus of Hourtin and Formosa has a luminous power equal to that of the Antifer hyper-radiant which cost more than double as much; and, further, that even the third-order lightning flash apparatus of Porquerolles has a luminous power equal to the hyper-radiant apparatus of Skroo (Fair Isle), although the cost of the latter was probably four times that of the former.

The weight of the Formosa apparatus is as follows:

	Tons.
Revolving parts, viz., panels, table reflector, floating drum and pivot..........................	2.8
Fixed parts, viz., mercury tank, supports, clockwork, etc..............................	3.3
Mercury................................	0.23
Total....................	6.33

The total cost of the apparatus, including all accessories and lamps, was 47,000 francs, or 1,680*l.*

*Four-wick burner.
†Constructed by Messrs. Barbier and Benard, Paris.

From the comparisons made above, it is abundantly clear that in giving preference to the lightning flash system, the Japanese lighthouse authorities took a step in the right direction. They are, indeed, to be congratulated upon having decided to adopt, for the atmospheric conditions of their coasts, that scientifically beautiful, mechanically perfect, and remarkably economical system of which the French coasts already possess so many brilliant and monumental examples in the optical apparatus supplied by Messrs. Sautter, Harle & Co. for the most powerful electric lights in existence, emitting short-duration (1-10 of a second) flashes up to 25,000,000 and even 38,000,000 candle power.

"DIMENSIONS OF CHANNELS FOR SURFACE DRAINAGE."

By Charles Edward Livesay, M. Inst. C. E.

From Proceedings Inst. C. E., Vol. CXXVIII, page 283.)

In a paper on "Discharge from Catchment Areas,"* Mr. James Craig sought to demonstrate that the ordinary formula for maximum discharge was erroneously based solely on the area, and did not take into account the shape of the catchment basin. In the investigation of the formula adopted, Mr. Craig considered the basin as divided into convenient triangles, having their apexes coinciding in the point of discharge of the whole country drained. Every catchment basin, however, in reality, is finally drained by the bed of the principal stream or river, of a certain length and slope, into which various minor streams flow at different points, each tributary having its own basin, with its special configuration and area, the whole of the affluents constituting the total discharge from the catchment area.

Hitherto, it has been virtually concluded that the minor valleys of any catchment area are so closely connected as to be able to void their contents at a uniform rate; and, accordingly, it has been inferred that a river channel, at any point, must be sufficient to pass the aggregate uniform discharge of the whole area above it. This could only be true if the rainfall, which is supposed to occur simultaneously over the whole tract, does not run out of any outfall until the contents of all the upper valleys arrive at that point. This, however, can never be the case, as all the outfalls are discharging at the same time, and those situated near the exit of the main channel may have partially or wholly emptied their catchment areas before the flow from the upper outfalls can reach them. Any section, indeed, of the channel must be adequate to pass the aggregate volume to be drained above it in a certain period of time, but not in the sense ordinarily accepted, and assumed by Mr. Craig, of a sluice (where a single reservoir or tank is concerned), toward which the surface water converges from all

*Minutes of Proceedings Inst. C. E., Vol. LXXX, page 20:.

points at a nearly uniform velocity. The conditions are entirely dissimilar in a long drainage channel, and it would probably be a closer approximation to the truth to say that any section of the channel must be capable of passing, not the whole, but the maximum of the combined discharges which may be flowing towards that section from above. If large enough to pass the maximum aggregate, it would be sufficient for any smaller volume which may run out before the maximum arrives. A consideration of the actual circumstances of a river flood will show that the above view must be truer to nature than Mr. Craig's assumption. The surface of the flood at any point in the course of the river rises gradually as the valleys nearest it discharge their contents, until the flood-level reaches its highest point, when the intensity of the flow indicates that the maximum of the combined discharges is passing; and when this has gone by, the level falls in consequence of the passage of combinations of smaller volume than the maximum, until the entire basin is emptied and the flood subsides. By any other supposition, an average height and volume is arrived at, which can never be the result of actual experience, although it may be convenient for practical purposes to assume such conditions.

In the year 1885, when in charge of an irrigation division in India, the author had to design certain alterations in the channel of a river to improve the drainage of over 200 square miles of the district of Cuttack, in Orissa; and he applied the principle of the above theory on that occasion. Although the works carried out according to his design have proved perfectly adequate under subsequent severe climatic tests, the author cannot affirm that their success was due to the application of his theory. A description, however, of the method of its application in actual practice may conduce to beneficial results.

This tract of country comprises the greater portion of the land irrigated by the Kendrapara canal of the Orissa circle, Bengal irrigation branch. The Kendrapara irrigation and navigation canal takes in its supply from the river Beropa, a tributary of the Mahanuddy, and is situated on two branches of the latter river. A minor irrigation canal, the Pattamundi, takes off the Kendrapara at its head, and is located on the right bank of the Beropa, the country concerned in the project lying between the two canals. The Gobri river occupies the lowest bottom of the cultivated lands irrigated by the above canals, and receives the excess rainfall and waste canal water, which it passes into the Gundakia river, a branch of the Beropa. The distributary channels from the Kendrapara canal are aligned on the highest ridges of the country, and divide the tract into a series of well defined valleys, which are numbered consecutively from 1 to 15. The outfall of each is indicated by a circle enclosing its number, and a line marking its entry into the bed of the Gobri as improved. The Gobri takes its rise in No. 6 valley; but the portion which has been improved, consisting of Parts I, II, and III, extends from

about a mile above the exit of No. 6 valley to the Kendrapara road bridge. The length of the natural bed of the Gobri, within the limits mentioned, was 30 miles 3,950 feet, with a total fall of 22.65 feet, or an average slope of 0.73 foot per mile. By realignment in cutting off bends, the total distance has been reduced to 24 miles 3,600 feet, with an aggregate fall of 22.37 feet, or 0.90 foot per mile. It was found useless to improve the lower part of the Gobri, from the Kendrapara road bridge to its outfall on the Chota Bramini river.

The chainage of the survey and section commences at the Kendrapara road bridge; and up to 15 miles 17 chains the fall of the bed is 0.5 in 5,000, or about the same as the natural bed of the river, which in this length is wide and of considerable capacity. There were many loops which had to be cut through; but above 15 miles 17 chains it was found possible, by the straight Gungadhur diversion cut of less than 2 miles, to avoid a detour of five miles 670 feet along the old bed. From this point to the head the channel is 9 miles 2,900 feet, with a fall of 1.5 in 5,000. At the upper end of the Gungadhur diversion cut, a little below the 17th mile, the old bed of the Gobri was closed, which permitted the drainage from 33.95 square miles of country, between Nos. 6 and 8 distributaries, to pass down the old bed without interfering with the discharge from above, which meets it at the 15th mile, where the river is much wider and better adapted to carry a greater volume.

The total area drained by the Gobri river is 206.74 square miles, including certain strips on the left bank of the Pattamundi canal, and the right bank of the Kendrapara canal, which are drained by syphon culverts under those canals, the fall of the land in all cases of deltaic rivers like the Mahanuddy and Beropa being inland from their banks. Nos. 1 and 2 areas lie between Pattamundi canal and the Beropa. No. 3 is a purely drainage bottom, and No. 4, originally a spill channel of the Mahanuddy river, called the Sookania Nullah, had been closed at its head by the Kendrapara canal. All these channels used to flow into the Beropa river; but on the construction of the Pattamundi canal, it was thought best to divert their drainage into the Gobri by the Sookania diversion cut, thereby introducing into that stream the rainfall of a tract 35.57 square miles, at a point where it had to carry the drainage of its own catchment area of 35.97 square miles. The land here is low, and the floods which stood over it for days together used to destroy the crops every year until the improvement scheme was carried out, when Part I of the channel was embanked, and then served to pass the combined discharges of Nos. 1 to 4 from the Sookania cut into the deeper bed of the Gobri beyond. At the outfall of No. 5 valley, an inlet sluice was constructed in the embankment to pass the discharge of that area when the level of the flood in the embanked channel allowed it to enter.

The project was first designed to provide for the drainage of a

rainfall of 4 inches over the whole tract in four days, the limit of time in which it is found that a submerged rice crop does not suffer. This is equivalent to a discharge of 1 inch of rainfall in twenty-four hours. In order to determine how these quantities of water combine in the improved river channel, the length of this channel, 24.68 miles, was first developed into a straight line, plotted to the scale of ⅓ inch to the mile, in which the outfall of each valley is marked by a circle bearing its number. Nos. 1, 2, 3 and 4 are outside the channel, but as they all pass through the Sookania cut, they are shown in a direct line according to the distance of each outfall from the head. Nos. 9 and 10 debouch first into the old bed of the Gobri, isolated by the Gungadhur diversion cut, and are exhibited according to their respective distances from the point of entry into the graded channel. The rest empty direct into the river, on the right or left bank, respectively. To ascertain graphically how the discharges of the valleys would combine in the improved channel, it was necessary to adopt a method of representation. If the valleys were of uniform width, they could be represented by their lengths; but as they vary in breadth, they can only be compared by their discharges under the given rainfall. It was, therefore, assumed that each valley might be represented by the length of a line ⅓ inch for every 100 cubic feet per second of discharge; for example, No. 4 valley, having a discharge of 286 cubic feet per second, would be equal to 0.95 inch.

In order to bring the discharge of all the valleys into the graded channel, that valley must be selected for determining the extent the exits must be shifted to effect this object, the distance of whose outfall from the graded channel, together with the length representing its discharge, gives the greatest total length. This condition is fulfilled by No. 9 valley, which has, therefore, been selected for calculating the amount the points of exit of all the valleys must be shifted downstream to bring their discharge into the graded channel, since what suffices for No. 9 valley more than suffices for all the other valleys. In a case where the exits of all the valleys are situated immediately on the banks of the main drainage channel, the length of the longest valley would naturally be taken for the distance of progression. The discharge of No. 9 valley is 818 cubic feet per second, and is represented by 2.73 inches; but as the outfall is 2.85 miles from the graded channel, the discharge would take longer to enter the channel than if the outfall had been on its banks, and therefore add 2.85 miles to the length of this valley. Assuming that all points of the flow in the river bed and minor channels, as represented by their lengths, move at the same rate, it follows that to bring the whole length of No. 9 into the graded channel, its actual point of exit should be moved $2.73 + 0.95$, or 3.68 inches in the diagram of the discharges.

The following volumes have to be provided for in the several parts:

PART I.

No. 2 valley; area 4.15 square miles; discharge 111.55 cubic feet.

No. 3 valley; area 18.39 square miles; discharge 494.32 cubic feet.

No. 4 valley; area 10.65 square miles; discharge 285.27 cubic feet.

Total area, 33.19 square miles; discharge 892.14 cubic feet.

PART II.

All above, area, 33.19 square miles; discharge 892.14 cubic feet.

No. 6 valley; area 35.97 square miles; discharge 966.87 cubic feet.

Total area, 69.16 square miles; discharge 1,859.01 cubic feet.

PART III.

All above, less No. 2; area 65.01 square miles; discharge 1,747.46 cubic feet.

No. 9 valley; area 30.45 square miles; discharge 818.49 cubic feet.

Total area, 95.46 square miles; discharge 2,565.95 cubic feet.

Comparing, however, these volumes with those actually observed in the river Gobri after an abnormal rainfall, they were found to be totally inadequate. On the 3rd August, 1880, the following quantities of rainfall were gauged: at Kendupatna, near the center of the tract, 10.53 inches; at Kendrapara, at the east end of the tract, 6.70 inches; at Marsaghai, at the thirty-ninth mile of the Kendrapara canal, 5.75 inches; at Byree, on the high-level canal, 6.90 inches; at Indpur, near the Pattamundi canal, 3.30 inches; and at Acquapudda, about 23 miles northeast of Indpur, 3.20 inches. These records show the widespread extent of the precipitation. For the tract now being dealt with, it will suffice to take a mean between the first and second returns amounting to 8.61 inches in twenty-four hours. The discharge of the Gobri immediately above the Kendrapara road bridge on that occasion was found to have been 5,881.40 cubic feet per second, or more than double that determined for Part III of the scheme. Although this circumstance does not invalidate the truth of the author's theory, it very clearly demonstrates that the assumption of 1 inch of rainfall passing in twenty-four hours was very far from being correct. Taking the catchment of Part III to be 95.46 square miles, 5,881.40 cubic feet per second as the actual volume to be provided for, and K the rainfall which probably runs off, $\frac{95.46 \times 5{,}280 \times 5{,}280 \times K}{60 \times 60 \times 24 \times 12} = 5{,}881\ 40$; and K=2.29 inches. For a rainfall, therefore, of 8.61 inches, it appears necessary to conclude that 2.29 inches run off in twenty-four hours. This is not surprising, considering that the country at that time of the

year must be saturated with rain and canal water, and incapable of absorbing much. The run-off would be much greater if it were not held back to a considerable extent by standing paddy crops and the distributary banks. The natural section of the Gobri river in Part III was amply sufficient for the passage of the observed discharge; and beyond cutting off bends or loops, no alteration was required in this portion of the channel.

By another observation of the river at 19 miles 41 chains, the discharge was found to have been 3,201.20 cubic feet per second, and taking the catchment area of Part II, 69.61 square miles,

$$\frac{69.61 \times 5{,}280 \times 5{,}280 \times k}{60 \times 60 \times 24 \times 12} = 3{,}201.20;$$ and $k = 1.83$ inches. To pass this volume through the Gungadhur diversion cut, a section of 70 feet base, with side slopes of 2 to 1 was given. This section, with a depth of nine feet and a fall of 1.5 in 5,000, provides for a calculated velocity of 3.99 feet per second, and a discharge of 3,160.08 cubic feet per second.

Above part 1, the observed discharge of the Sookania cut was found to be 1,023.21 cubic feet per second. Taking the catchment area of Part I at 33.19 square miles,

$$\frac{33.19 \times 5{,}280 \times 5{,}280 \times k}{60 \times 60 \times 24 \times 12} = 1{,}023.21, \text{ and } k = 1.38 \text{ inches.}$$

The section given to carry this volume in the embanked channel of Part I was, base 34 feet and side slopes 2 to 1, which, with a depth of 7 feet and a fall of 1.5 in 5,000, gives a velocity of 3.14 feet, and a discharge of 1,055.04 cubic feet per second. As, however, a depth of 9 feet was found necessary in Part II, the same depth was adopted in Part I, the banks being constructed 12 feet above the bed, or 3 feet above the water-level, in case the level should be raised by the swollen state of Part II. An outlet sluice was also built in the right embankment, to drain off any rainfall which might accumulate on the low land behind it before the flood-level in the embanked channel should fall low enough to admit of its passage into the main river. Since the scheme was carried out, several abnormal falls of rain have taken place at Cuttack, quite as heavy as the one recorded in August, 1880; but no damage has occurred to crops in the cultivated lands in the valley of the Gobri river, indicating that the preventive measures have been successful.

To apply the theory formulated in this paper, it will always be necessary to define the extent of each minor valley in the catchment basin of a drainage area, and to collect accurate information of the rainfall to be dealt with. For the configuration of the minor valleys, with good maps, it will doubtless be a sufficient approximation to assume the watershed between two minor valleys to lie midway between the tributary streams; but if greater exactness were required, a series of cross-sections at long intervals from one stream up to the dividing ridge would demarcate

the ridge, or the ridge itself might be surveyed. For the rainfall data, observations would have to be taken as to the loss by evaporation and absorption in different localities, for which closer and more discriminating observations are needed, as very little is known of this loss. There must be wide differences due to the land being cultivated or unbroken, forest or grass, rocky or a mixture of all descriptions; and only actual observation would show what portion of the run-off should be provided for. When, however, the surface drainage of towns is considered, very accurate data would be available for each block to be dealt with, as to extent and configuration, as well as to meteorological conditions of the whole area; and it is probable that, in these cases, the theory advanced may be applied with advantage, especially as regards the safe and economical removal of storm-water.

THE PURIFICATION OF THE THAMES.

By William Joseph Dibdin, F. C. S., F. I. C.

(From Proceedings of the Institution of Civil Engineers (England), Vol. CXXIX, p. 80.)

The scheme adopted by the late Metropolitan Board of Works for the treatment of the London sewage at the Barking Creek and Crossness outfalls was explained before the Institution in January, 1887,* by the author. It is now proposed to show, first, the work carried out in accordance with it in effecting the purification of the sewage of the metropolis; secondly, the effect of that work in freeing the river from the task formerly imposed upon it in disposing of the raw sewage of five millions of people; and, thirdly, the best method of effecting still further improvement if desired.

In the paper referred to it was shown that in determining the most effectual and at the same time economical method of treating sewage, the effluent from which could be turned into a tidal river of good volume in relation to that of the sewage, the following points were to be considered: The detrimental effect of an excess of chemicals; the limited reduction of organic matters in solution by chemical treatment; the use of iron salts as an auxiliary to lime when necessary; the action of bacteria in completing the process of purification; the objections to the filtration of crude sewage; the final purification of the effluent by proper filtration through land; the subsidiary treatment of the effluent when necessary; aeration as an aid to bacterial life; the disposal of the sludge.

The method adopted was first submitted by the author to the Royal Commission on Metropolitan Sewage Discharge in 1884, as will be seen from the following extract from the minutes of evidence, p. 113 *et. seq.*: "We found that whatever process of chemical precipitation might be used which could be applied in

*Minutes of Proceedings of Inst. C. E., Vol. LXXXVIII, p. 155.

practice would have but a very slight effect in removing the dissolved organic matter. Then we came to the conclusion that the only result which might be expected would be the removal of the suspended matter, and that we might neglect for this purpose the whole of the dissolved matter. * * * Proceeding with our experiments, we found that the use of those four grains of lime and the one grain of protosulphate of iron was sufficient, practically, to remove the whole of the suspended matter and the grosser part of the offensive odor. In fact, we were satisfied that it would do all that was required to be done with the London sewage at Barking and Crossness, and that the effluent, if discharged into the Thames there, would certainly hardly be noticeable, and by the time it was thoroughly diluted with river water that it would certainly be to all intents and purposes invisible; that the present black stream that is seen at the point opposite the present sewage works would be entirely done away with, and that all effect of the sewage in the river in point of appearance would be annihilated. The matters in solution in the sewage would still be there, but the matters in solution are those which are more readily oxidised by the action of the river, and so would disappear at a much greater rate than they do at present."

From the following extracts of the "conclusions and recommendations" of the commission, it will be seen that the commission substantially agreed with the above suggestions:

"3. We are of opinion that some process of deposition or precipitation should be used to separate the solid from the liquid portions of the sewage.

"4. Such process may be conveniently and speedily applied at the two present main outfalls.

"5. The solid matter deposited as sludge can be applied to the raising of low-lying lands, or burnt, or dug into land or carried away to sea.

"6. The entire process of precipitation and dealing with the sludge can be and must be effected without substantial nuisance to the neighborhoods where they are carried on.

"7. The liquid portion of the sewage remaining after the precipitation of the solids may, *as a preliminary and temporary measure*, be suffered to escape into the river.

"10. But we believe that the liquid so separated would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a *permanent* measure. It would require further purification, and this, according to the present state of knowledge, can only be done effectually by its application to land."

The "safety clause," as No. 10 may be called, is now fully met by the results of the experimental filtration operations hereafter described, which can be applied in a far more convenient and economical manner than that contemplated by the commissioners, whenever the increase in the quantity of the sewage may

render such further action desirable. In accordance with the above suggestions and the report of the royal commission, the late Metropolitan Board of Works instructed their engineer to proceed with the construction of the necessary works. The sewage was to be treated chemically by small quantities of lime and iron at the existing outfalls; the effluent was to run directly into the river at these points, and the sludge was to be carried to sea in specially constructed vessels. In the absence of knowledge of the action of bacteria in relation to the filtration of the sewage effluent, no action in this respect had been decided upon. The works constructed for the purpose of carrying out the operations indicated are described in the paper* on "The Main Drainage of London," by Messrs. J. E. Worth and W. S. Crimp, MM. Inst. C. E.

The sewage north of the Thames is delivered at the Northern outfall by three main sewers. After passing the screens it receives its proper quantity of lime, which varies with the strength and rate of flow of the sewage. At the liming station the lime, after being weighed as it is taken from the store, is placed in large mixing trays 15 feet in diameter, fitted with four revolving arms, to each of which a heavy rake is suspended. Sufficient water is then let into the tray to slake the lime. This being accomplished, more water is added and the mixing-arms are rotated by steam-power, the lime and water being thus stirred into a cream as dilute as possible. Water is continually admitted and the cream of lime flows out into a channel leading to the lime-water tanks, where it meets a large access of water, and is thereby diluted and carried into the tanks, six in number, each having a capacity of about 100,000 gallons. The mixture of the lime and water is further facilitated by the fall from the trough into the tank, and thus the whole bulk is kept in agitation until the tank is full. As required, the lime-water so obtained is forced by centrifugal pumps to an overhead tank placed on the top of the boiler-house and lime-store, whence it is drawn off as required. At first, the lime-water was made with crude sewage and the top liquor drawn from the sludge-settling channels, but the extent to which the lime is destroyed by these was so great that they have been replaced at Crossness by river water, with such marked advantage that the same plan will be adopted in connection with the new liming station at the Northern Outfall works.

After receiving the lime, which under the new system will be entirely in solution, as originally intended, the sewage passes the iron-water station where the solution of iron-sulphate is added. No special mixing arrangement is applied, as the rolling motion of the sewage as it passes along the sewer is found to answer the purpose. The iron salt is dissolved in a tank of water heated by a steam-coil, and the concentrated solution thus obtained is sufficiently diluted and passed direct into the sewer containing the

*Ante, p. 49.

already limed sewage. The precipitation thus effected by the combined action of the lime and iron is completed in thirteen precipitation-channels.

The method of discharging the sludge from the precipitation-channels to the sludge-settling channels is by sweeping the deposit obtained from the action of precipitation through culverts leading under the main sewer to the receiving chamber at the engine-house, whence it is pumped into the settling channels. On its way to these the sludge is again passed through gratings to collect rags, etc., which may have escaped the first filth-gratings. The quantity of solid matter extracted by the combined action of the double sets of gratings is between 80 tons and 100 tons per week, of which large quantities have been utilized as manure. A destructor-furnace is built close to the filth hoist, or first set of gratings, and when necessary is used for calcination of the refuse.

The following are the results of an analysis of a sample of this refuse:

Analysis of Filth from Gratings at the Northern Outfall.

		Per Cent.
Moisture		77.2
Wood		1.0
Coarse string and fibre		0.7
Coarse rags		0.4
Fine rags, pulp, etc		16.6
Very fine fibrous matters, sand, earthy matter, etc., containing volatile organic matter, of which one-fiftieth is nitrogen	51.5	
Phosphoric acid	2.6	4.1
Sand, earthy matter, etc	42.2	
Moisture	3.7	
	100.0	100.0

The amount of nitrogen in the fine fibrous and earthy matter is only 0.041 per cent, and of phosphoric acid 0.11 per cent of the whole. While, therefore, its manurial value is but slight, it would appear to be well suited from its fibrous nature for making coarse paper; and experiments on a working scale are in progress with a view of ascertaining its adaptability for that purpose.

After the sludge has settled and the top-water has been drawn off by means of siphons, the sludge is let into the storage-tanks under the settling-channels, whence it is forced by direct-acting pumps to the ships. Formerly the water drawn from the settled sludge was pumped to the liming-station, but alterations have been made which enable this liquor to be separately treated with lime and iron, and after such treatment to settle in the sewage-precipitation channels.

The sewage of London south of the Thames is carried by a large sewer to Crossness, where the precipitation works are much

more compact, in consequence of local conditions. As the whole of the sewage is screened, it was not necessary to erect an additional filth-hoist as at the Northern Outfall works, except on a small scale for the sludge. The lime water was formerly put into the sewer before the pumps, but it is now added to the sewage after them. The liming-station is admirably suited to the requirements of the works, practically the whole of the lime being in solution before its addition to the sewage. The lime mixers at Crossness are similar to those at the Northern Outfall, and are 12 feet in diameter. The charge of lime varies between 1 ton and 1½ tons, to meet the flow of sewage. The lime, having been formed into a cream, is discharged from the mixers into a culvert,where it meets with river water pumped for that purpose, and then through a series of tanks, six in number, each of a capacity of about 40,000 gallons. In two of these tanks a pair of Gabbott stirrers, 12 feet in diameter, are fixed. The lime water passes first through one of the end tanks and thence over weirs into four others successively, into the lime water culvert. The quantity of river water pumped for this purpose is between 2,500,000 gallons and 4,000,000 gallons daily. The quantity of commercial lime taken for making the lime water is about 110 grains per gallon, of which, on an average, about 70 per cent is in solution. It will be noticed that it is necessary to employ an excess of lime to allow for the hard-core, and the neutralization of a portion of the lime by the carbonic acid in the river-water employed for its slaking and solution. The iron-water is made at Crossness by the simple agitation of the crystals of iron salt with water in an ordinary mixing-mill from which the rollers are removed, stirring arms being substituted in their place, the effect being equally efficacious with that of the steam-coil at the Northern Outfall works. The precipitation-channels at Crossness are not fitted with the telescope weirs for the purpose of emptying the channels, but with the ordinary floating arms, the bulk of the effluent, however, falling over the weirs as at Barking Creek. In other respects these channels are almost identical. In consequence of the more effective arrangements for making lime water at Crossness, the results have been much more satisfactory than those at Barking Creek. The method of collecting the sludge, settling it, and loading the ships is identical with that at the Northern Outfall works.

The fleet of vessels employed for the purpose, carried to sea during the year 1894, 2,052 cargoes of sludge, of which quantity 1,380 cargoes, containing 90.7 per cent of moisture, were conveyed from the Northern Outfall, and 724 cargoes, containing 91.25 per cent of moisture from the Southern Outfall. The discharge takes place in the Barrow Deep, commencing at a point 10 miles east of the Nore, and proceeding thence from 5 miles to 10 miles down that channel, which is unused for traffic, being about half way between the Swin Channel, or route for vessels proceeding north, and the Princess Channel, which is the ordi-

nary route for vessels going south. As the sludge is discharged from the bottom of the vessel, some 10 feet under water, and is thus agitated with the sea-water by the action of the twin-screws, the diffusion of the sludge in the water in the wake of the vessel is very complete, so much so that when there is but a slight ripple the visible effect of the sludge is lost after a few minutes. The sand and earthy matters soon separate by subsidence, and the animal and vegetable debris is rapidly consumed by the organic life in the sea-water. This is evidenced by the fact that, although about 10,000,000 tons of sludge have now been deposited in this part of the estuary, the most careful microscopical examination and chemical analysis fail to detect more than the merest trace of the mineral portion of the sludge, either in dredgings from the bottom of the channels or on the surface of the sandbanks, which are now as clean as in 1888, before more than a few trial cargoes had been discharged. The cost of this operation has been found to work out to about 4¼d. per ton of sludge.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—4th OF AUGUST, 1897.

A regular meeting (the 369th) of the Society was held in its rooms 1736-9 Monadnock Block, Chicago, Ill., on Wednesday evening, at 8 o'clock, 4th of August, 1897, President Thos. T. Johnston in the chair.

The minutes of the previous meeting were read and approved.

The secretary reported for the Board of Direction: Applications for admission to the Society from Arthur John Cox, as member, and Robbins Yale Maxon, as junior, which were read, placed on file and referred to the Membership Committee.

The Entertainment Committee reported that a better rate of fare could be obtained by postponing the excursion to Niagara Falls until about 23d September, at the time of the ceremonies of the Grand Trunk Ry. Co. over their new arched bridge across the St. Lawrence river. Discussion of the subject followed, and the action of the committee was approved. Due notice of the date of the excursion to be sent members.

As there was no further business the chair announced the paper of the evening, "The Internal Hydrostatic Pressure in Masonry, with Especial Reference to Masonry Dams," by Messrs. Arnold, Emil Broenniman and Harry Hurson Ross. Mr. Broenniman was introduced and read the paper. At its conclusion Messrs. Bainbridge, Beardsley, Curtis, Bley, and the chair entered into the discussion.

Adjourned.

REGULAR MEETING—8th OF SEPTEMBER, 1897.

A regular meeting (the 370th) of the Society was held in its rooms on Wednesday evening, at 8 o'clock, the 8th of September, 1897. President Thos. T. Johnston in the chair.

The minutes of the previous meeting having been put in print and sent to members were, upon motion, approved as printed.

The secretary reported for the Board of Direction the election of Hiram J. Slifer, Arthur J. Cox and John Williamson as members, and Robbins Yale Maxon as junior.

The subject of the evening was Motocycles. Mr. H. M. Brinckerhoff, chairman of the committee having the matter in charge, was introduced and proceeded to read communications and articles specially prepared for the occasion. During the reading opportunity was given for discussion of the several phases of the subject as developed in the matter read. At the conclusion of the reading a general discussion was had in which the following named gentlemen participated: Messrs. L. L. Summers, Bion J. Arnold, J. S. Stephens, G. Herbert Condict, general manager Englewood & Chicago Storage Battery road, and others.

Mr. Isham Randolph, chairman of the Entertainment Committee, reported arrangements for the excursion about completed and read letters of invitation from cement companies to partake of hospitalities en-route. The report was accepted.

Adjourned.

REGULAR MEETING—6th OCTOBER, 1897.

A regular meeting (the 371st) of the Society was held in its rooms 1736-9 Monadnock Block, Chicago, Ill., on Wednesday evening, at 8 o'clock, the 6th of October, 1897. President Thos. T. Johnston in the chair.

The minutes of the previous meeting were read and approved.

Mr. J. J. Reynolds submitted a report of the Committee on Amendments to the By-Laws, recommending that Sections 5 and 7 of Art. II. on "Nomination and Election of Officers" be amended to read as follows:

Sec. V. "All petitions presented shall be canvassed by the Board of Direc-

tion, and if it is found that no nomination has been made for one or more officers, the Board shall make the nomination or nominations required to fill out the ticket."

Sec. VII. "Each nominee shall be promptly notified of his nomination. If any nominee shall be found by the Board of Direction ineligible for the office for which he is nominated, or should a nominee decline the nomination, his name shall not be sent out. The Board of Direction shall make additional nominations when necessary to complete one ticket, up to the time the ballots are sent out."

The chair called for remarks on the proposed amendments, whereupon Mr. T. L. Condron arose and presented an amendment to the amendments, when full discussion, comparison and explanation of the two amendments was had and free expression of members given. The question was then called for and a vote taken on the amendment to the amendments, which was lost.

The original report was then called and after further discussion was adopted, a letter ballot ordered sent out to be counted at the next regular meeting in November. Mr. A. M. Feldman moved that Mr. Condron's amendment be referred to the Board of Direction, but the motion being out of order could not be entertained at this time.

Mr. G.A.M. Liljencrantz made report for the Library Committee, and read the following resolutions:

Be it Resolved, That the Board of Direction is hereby requested to consider the desirability of donating to the Crerar Library such volumes as are not to be bound for our own Library, and of issues prior to the current year, provided that the Crerar Library will agree to have such volumes bound and kept accessible to the Members of this Society, and,

Be It Further Resolved, That the Board of Direction is hereby authorized to act in this matter, after due consultation has been had with the Officials of the Crerar Library, and

Be it Further Resolved, That the Western Society of Engineers is highly appreciative of the kindly co-operation offered by the Crerar Library, and that the policy of the Society is in the same direction as that of the Library Officers.

Mr. J. H. Spengler moved the adoption of the resolutions. Carried.

Mr. J. C. Bley, for the sub-committee of the library, requested that members suggest such books for purchase for the library as will be valuable for reference.

The chair then stated that Mr. Isham Randolph, chairman Entertainment Committee, had prepared a report to be read tonight but was called out of the city, so the report would be delayed to a subsequent meeting.

Mr. Feldman here renewed his motion that Mr. Condron's amendment be referred to the Board of Direction at their next meeting. Carried.

The chair stated that the Society had been enjoying the courtesies of a number of people on their excursion to the East, and suggested that it would be proper at this time to take cognizance of these courtesies in an appropriate manner.

Mr. Condron made motion that the chair appoint a committee to prepare, in co-operation with the Entertainment Committee, resolutions of thanks expressive of the very lively appreciation of the generous treatment the Society received.

Mr. G. M. Wisner, member of the Entertainment Committee, stated that the committee already had the matter under consideration and would see that it had proper attention. Mr. Condron withdrew his motion, and Mr. J. J. Reynolds, in order to have the matter take formal significance as the Society's action, moved that the Entertainment Committee be instructed to prepare resolutions of thanks to those through whose courtesy the Society was so delightfully entertained on the recent excursion. Carried.

At the request of President Johnston, Mr. Liljencrantz took the chair. Mr. Johnston then moved that the special thanks of the Western Society of Engineers be extended to the Lehigh Valley R. R. Co. for kindly courtesies extended to it on the recent trip to New York city and return. Unanimously carried.

By several members it was stated that the engineers of Philadelphia were much disappointed that the plan for the Society's visit to their city was not carried out, as preparations to receive and welcome the Society had been arranged, and an enjoyable time was in waiting. Mr. Johnston added that a cordial invitation, asking the privilege of entertaining the Society, had been received from the engineers of Philadelphia, but owing to change in the plans it became impracticable to visit that city; that proper expression in recognition of the cordial disposition and invitation will be given in due time.

Mr. Condron stated that there was one action which the Entertainment Committee was not qualified to take, that of a vote of thanks to the Entertainment Committee for the magnificent excursion, and moved that now a vote of hearty thanks be tendered that committee for the delightful and perfectly arranged excursion which was so thoroughly enjoyed by all the participants. Carried.

The discussion of "the Excursion to the East" was the next order of business.

Reference was made to the Bethlehem Iron Works, of South Bethlehem, Pa., which were visited and their representative, Mr. H. F. J. Porter, being present, responded to the call made for him. He was questioned regarding the main features of the works observed by the visitors and gave a variety of interesting information and explanation, all of which will appear in the Society's Journal at an early date.

Adjourned.

SPECIAL MEETING—20th OCTOBER, 1897.

A special meeting (the 372d) of the Society was held in the rooms of the Technical club, 230 Clark street, at 8 o'clock, Wednesday evening, 20th of October, 1897. President Thos. T. Johnston in the chair. One hundred and two members and guests, including ladies, present.

The reading of the minutes of the previous meeting was dispensed with.

Committee reports being called for, Mr. Isham Randolph, chairman of the Entertainment Committee, read report of the Society's trip to the East in September. Before action was taken upon this report the president read an auxiliary report reciting the history of the Society's extended excursions. The report was adopted and a vote of thanks extended to the committee for its efforts in entertainment.

Mr. Byron B. Carter, on behalf of Mr. John W. Alvord, who was unavoidably absent, and who is especially interested in the matter, read the following resolutions:

WHEREAS, Through the beneficence of the founder of the Crerar Library, the engineering profession in this vicinity will be afforded a long desired opportunity to see established and maintained a technical reference library of the highest order;

AND WHEREAS, As the accumulation of a reference library is the work of years, requiring diligent work along very many lines of thought, and as the librarian of the Crerar Library, although himself an expert in engineering literature, has indicated a willingness to accept suggestions and co-operation from this Society,

Be it Resolved, That the president of this Society be and is hereby authorized to appoint a committee to co-operate with the John Crerar Library, acting under the advice and direction of the librarian of said library, said committee to consist of such number of members as the president shall deem necessary for the purpose, and shall have represented in its membership as many branches of engineering as possible, so that standard literature along all lines of engineering work may be promptly called to the attention of the librarian;

And be it also Resolved, That the thanks of this Society be tendered to the directors and the librarian of the Crerar Library for the opportunity thus afforded this Society.

Mr. G. A. M. Liljencrantz commented upon the resolutions, and in order to indicate the importance of carefully selecting members for the co-operating

committee who are willing and have time to act promptly in the matter, he read the following letter from the librarian of the Crerar Library:

THE JOHN CRERAR LIBRARY,
Chicago, October 12, 1897.

G. A. M. Liljencrantz, Esq., Assistant Engineer, U. S. War Department, 1637 Indiana avenue, Chicago, Ill.

MY DEAR SIR: Referring to our conversations of the past week, I desire to express formally my appreciation of the offer of the Western Society of Engineers to assist us in the collection of a valuable engineering library. We are now ready to begin the purchase of books on engineering, and I should be very glad to have the co-operation of a committee appointed by the Society or by its library committee. The material is in a shape that would not, I think, make undue calls upon their time.

The frequent demands for books on engineering makes me anxious to begin work at an early date, and I hope that the Society will act promptly in the matter. Yours very truly,

C. W. ANDREWS, Librarian.

He then stated that Mr. Andrews was present.

The chair recognized Mr. Andrews and expressed the pleasure of the Society at his presence, stating that the cause of the resolutions introduced marks an epoch in the Society's history in bringing it in touch with the Crerar Library. Mr. Andrews, in response to invitation, arose to speak, and said that the expression of thanks ought to be addressed to the directors of the Crerar Library and not to him personally, as he was simply carrying out their desires, that it would be presumption for any one man to say that he would select the best books on so many subjects as the scheme of the Library covers; that he knew he could get assistance here which would be of great value, not only to this Society, but to engineers outside of it, and to young men who hope to be engineers in the future. Mr. J. C. Bley moved to amend the part of the resolutions referring to a vote of thanks so as to include the directors and Librarian.

The amendment was accepted and on motion the resolutions were adopted.

The chair announced the subject of the address, "Gliding Experiments," and introduced Mr. Octave Chanute, who proceeded at once to the subject. Views of flights in the upper air at a variety of stages were thrown on the canvas, explanations of mechanism of the machines given, manner of starting and alighting, and the difficulties to be met and surmounted before success in air navigation can be attained. Mr. Chanute then introduced Mr. Herring, his assistant in the experiments, who proceeded to indicate somewhat the feelings of one while soaring in the air, with other interesting remarks.

Mr. L. L. Summers called attention to Mr. Chanute's painstaking labors, and the sound principles upon which he is working.

The meeting adjourned, gratified with the pleasure and information derived from the addresses.

NELSON L. LITTEN,
Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid in completing valuable volumes for our files.

Since the last issue of the Journal, we have received the following as gifts from the donors named:

S. S. Greeley—Drainage Law of 1889.
Telegraphing Among the Ancients, A. C. Merriam.
Vol. VI. Proceedings Western Soc'y of Engineers, January to June, 1881.
No. 1 & 8, Journal Ass'n Eng. Societies, 1893.
Michigan Engineers' Annual, 1896.
The Technic, 1896.
The Technograph, May, 1896.
Bureau of Labor, Statistics and Mines, Tennessee.—6th Annual Report, 1896.
U.S. Bureau of Foreign Commerce.—Consular Reports, July and August, 1897.
U. S. Dept. Interior.—Water Supply and Irrigation Papers of U. S. Geol. Survey.
U. S. War Dept.—Report of Board to Create a Deep Water Harbor at Port Los Angeles or at San Pedro, Cal.
U. S. War Dept.—Annual Report of the Chief of Ordnance, 1896.
U. S. Chief Engineers.—Various Surveys, Harbor and River Improvements.
Chief Engineer's Office, U. S. A.—Conclusions adopted by the French Commission in reference to Tests of Cements.
Sanitary Dist. of Chicago.—Proceedings of Board of Trustees, June and July, 1897.
Mich. Engineering Society.—Annual for 1897.
Geo. S. Morison.—An Address of the 71st Annual Commencement of the Rensselaer Polytechnic Institute, June 16, 1897.
Carnegie Library, Pittsburg.—1st Annual Report, 1895.
Keuffel & Esser Co., New York, 1897.—Catalogue.
Institutton of Mechanical Engineers, London.—Proceedings, July, 1896.
Institution of Civil Engineers, London.—Proceedings, Vol. CXXVIII, 1897.
Engineering Society, University of Michigan.—The Technic, 189.7
New England Cotton Manufacturers' Association, 1897, Boston.
Technical Publishing Co., Ltd.—Practical Engineer Pocketbook for 1898.—Manchester, England—A Valuable Reference Book.
From Industrial World.—Valve-gears, by H. W. Spangler, P. A. Eng'r U. S. Navy.
.Valves and Valve-Gearing, by Chas. Hurst.
U. S. Education Bureau.—Report of Com'r Ed., 1895-6, Vol. I.
Northeast Coast Inst. Engineers and Shipbuilders.—Trans. 13th Session, 1896-7. Vol. XIII.
Cloud, John W., Sec'y.—Proceedings 31st Annual Convention, M.C.B., June 8, 9, 10 and 11, 1897.
Sanitary Dist. Chi.—Proceedings Board of Trustees for 1896.
U. S. Census Office.—11th Census Report on Population U. S.
" " " 11th Census Report on Farms and Homes.
S. S. Greeley.—Vol. I, Rept. of Geol. Survey, Ohio, 1873.
U. S. Geological Survey, Dept. Interior.—Bulletins Nos. 87-127-130-135-136-137-138-139-140-141-142-143-144-145-146-147-148.
Melcher, C. W.—8 Copies of Compressed Air, 1896-97.
Cilley, Frank H.—Some Fundamental Propositions Relating to the Design of Framework.
Woods, Mrs. H. deK.—Librarian, Catalogue of the David L. Barnes Library.
University of Wisconsin.—Bulletin No. 1. Track, by L. F. Loree, C. E.
" " 2. Some Practical Hints in Dynamo Design, by Gilbert Wilkes, E. E.
Bulletin No. 3. The Steel Construction of Buildings, by C. T. Purdy, C. E.

University of Wisconsin—Bulletin No. 4. The Evolution of a Switchboard, by Arthur V. Abbott, C. E.
Bulletin No. 5. An Experimental Study of Field Methods which will Insure to Stadia Measurements greatly increased accuracy, by Leonard S. Smith, B. C. E.
Bulletin No. 7. Emergencies in R. R. Work, by L. F. Loree, C. E.
Bulletin No. 8. Electrical Engineering in Modern Central Stations, by Louis A. Ferguson, S. B.
Bulletin No. 9. The Problem of Economical Heat, Light and Power Supply for Building Blocks, School Houses, Dwellings, etc., by G. Adolph Gerdtzen, B. S.
Bulletin No. 10. Topographical Surveys, Their Methods and Value, by J. L. Van Ornum, C. E.
Institution Civil Engineers, London—List of Members, September, 1897.
Vol 129, Minutes of Proceedings, Part III, 1897.
University of Minnesota.—Vol. 5. The Engineers Year Book, May, 1897.
U S. Consular Reports.—No. 205, October, 1897.
General Index to Monthly Reports. Vol. 42 to 54.
U. S. Wind Eng. and Pump Co.—Catalogue 1897.
U. S. Public Documents.—Catalogues from February, 1895, to August, 1897.
Condron, T. L.—No. 1, Vol. VII. The Rose Technic, 1897.
Lewis Institute.—First Annual Register, 1897.
City Engineer, Grand Rapids, Mich.—24th Annual Report, Board Public Works.
Settan, G. W.—Timber. An Elementary Discussion of the Characteristics and Properties of Wood, U. S. Agricultural Department.
Conclusions Adopted by the French Commission in Reference to Tests of Cements.
Annales des Ponts et Chaussees.—1st Partie. Memoir et Documents relatifs. A. L'Art des Construction, 1897.

The library and reading rooms are open from 9 A. M. to 5 P. M., on week days, except Saturday, until noon.

TO MEMBERS.

The Library Committee wishes suggestions as to good engineering books, new or old, that are desirable for our library. The aim is to give the greatest good to the greatest number of our members possible with the funds at our command and the committee, composed of few members, cannot well judge wisely to meet the various needs of our membership.

Will each member please send to the Secretary of the Society the title of one or more books which he considers useful and authoritative in some line of engineering work. Please state title as fully as possible together with the names of author and publisher, etc.

Any suggestions in regard to the library in general or in any detail will be gladly received.

LIBRARY COMMITTEE.

VOL. II. NO. 5. DECEMBER, 1897.

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DRAINAGE CANAL.

Lecture by Isham Randolph, Chief Engineer Sanitary District of Chicago, November 30, 1897, at Central Music Hall.

Speaking to a Chicago audience of Chicago's growth and present prosperity might seem like "carrying coals to New Castle." But it is not so. Our lives have been cast upon times which are full of activity, thought and achievement; for us the present is the essence of existence, the future, the goal to which we are pressing, and the past, with far too many, is but dim and nebulous remembrance. Who gives enough time for retrospection to picture the longshore line of Lake Michigan without a human habitation? Who remembers that within the short span of a human life the mighty navies which float upon her broad bosom have sprung into existence? Presently I shall show upon the screen a map of Chicago's site as it was in 1812; twenty-five years after which she took on the dignity of incorporation; thirty four years later her population was somewhat in excess of 300,-000 souls.

On the 9th of last October we commemorated an event which rendered nearly 100,000 of her inhabitants homeless, swept into nothingness $196,000,000 worth of property. We all know today that Chicago is great, but who can give the measure of that greatness in the terms of volume and extent which fill her statistics? An incorporated area on 187 square miles, a population by the last census of 1,616,000 souls; 2,570 miles of streets, 1,183 miles of which are paved and improved; a water system comprising ten miles of lake frontage, with a daily capacity of 484,000,000 gallons, six main pumping stations, whose daily output is given as 357,500,000 gallons, 1,692 miles of water mains veining her streets, all built at a cost of $25,369,215. She has 1,306 miles of sewers, built at a cost of $17,661,000. The Chicago river, vile, crooked, open sewer that it is, has a dock frontage of forty-one

miles. The business of this port, as shown by reports for 1886, amounted to 6,428,000 tons of arrivals, in 8,477 vessels, and 6,537,-000 clearances, carried in 8,552 vessels, or a total of nearly thirteen million tons carried in 16,999 vessels—4,829 more arrivals than are registered from the port of New York, and only 829 less than all the arrivals and departures from Boston, Philadelphia, Baltimore, New Orleans and San Francisco for the same period.

From here twenty-one lines of railroads radiate, having a mileage of 54,272 miles. Her elevator capacity is rated at 46,500,-000 bushels, and her bank deposits aggregate nearly $187,000,000.

But we will weary with a recital of her statistics. Enough has been said and yet the half has not been told what made Chicago as she is today, the empire city of the west. Her geographical position was recognized by the men who build empires—men of courage, men of brains, men of enterprise. What made Chicago great? Men. Men who could plan wisely, men who could command, men who could execute, and in the front rank of these were the men of our profession—the engineers. Who laid out your streets, who built your tunnels, who built your water systems, who built your docks, who laid out your parks, who built your railways? The engineers. Who built those railroads which vein the continent, bringing to your store-houses the fruitage of the universe and pour into your homes the luxuries and the treasures of art from many lands; the railroads, which carry hence the product of your manufactories and your machine-shops and distribute from your great depot of supplies food for the millions of the earth? The engineers.

Back in 1869 an organization had birth which has grown and grown and grown until it is today the Western Society of Engineers, with hundreds of members scattered all over this broad land and even in lands beyond the sea. The first president of that organization was Roswell B. Mason, engineer and statesman; he who was the mayor of this city in the heart-rending, soul-stirring times of 1871. We may speak the names of our dead in public praise which was their unclaimed due in life. What have you to say of E. S. Chesbrough? He needs no prouder monument than Chicago itself. What of O. M. Poe, in whose memory the Sault Locks will pour libations for centuries to come? What of John Newell, who left behind him the Lake Shore Railroad as a splendid memorial? What of those other tried and noble men who have gone beyond the cares and troubles of earth? Willard S. Pope, Jotsberg, Gottlieb, Booth and other past masters of our craft, and what of the younger men whose names are being written on the scroll of fame? There is G. W. G. Ferris, Jr., whose name is linked with memories of the White City; and Scherzer, whose fruitful genius evolved the rolling lift bridge. But I may not stop to praise our living or our dead. I am here to speak of a great enterprise. The City of Chicago has waxed wealthy, and with the increase of her wealth and population, her filth did much more increase until the people cried out for relief.

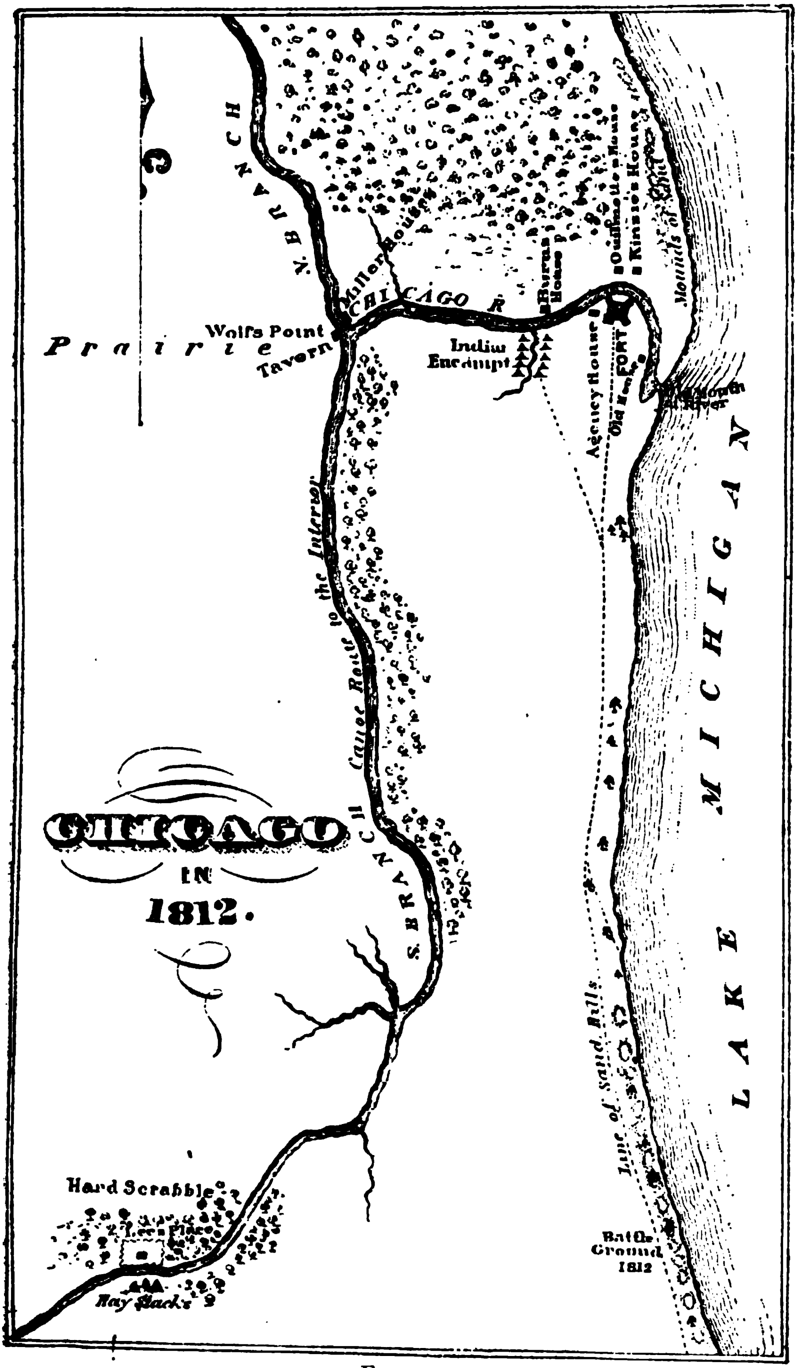

CHICAGO
IN
1812.
Prairie
Wolf's Point
Tavern
N. BRANCH
CHICAGO R
Indian Encampt
FORT
Agency House
Kinzie's House
S. BRANCH
Canoe Route to the Interior
Line of Sand Hills
Battle Ground 1812
Hard Scrabble
LAKE MICHIGAN

FIG. 253.

Way back in the eighties this cry went up, and in 1885 the Commission of Pure Water Supply was formed. This commission made a thorough investigation of the things that might be done to bring relief to the city. The chief of that commission was Mr. Rudolph Herring, with Mr. Samuel G. Artingstall and Mr. Benizette Williams as assistants, and Mr. L. E. Cooley. The result of these investigations was that they recommended a cut through the divide which separates the basin of Lake Michigan from the waters which flow to the Mississippi.

In 1889 the Sanitary District was formed by an act of the Legislature, and the first trustees were then elected. Two years were lost in passing resolutions which went nowhere, but at last the trustees recognized that they must put their shoulders to the wheel, and the work went on. On the third of September, 1892, the first blast was fired and the work was inaugurated.

Is there anything in the Chicago of 1812, see Fig. 253, that made the destiny manifest? Fig. 253 shows old Fort Dearborn, and scattered around it the few trading houses of that time, the sand dunes, and also the battle ground of 1812. Since then there has been a great transformation, and our map presents a different scene.

FIG. 254.

Fig. 254 does not present the map that I expected, but still it shows some very good looking men. This was the Board as constituted when I first became acquainted with it. There is our president, Mr. Frank Wenter, who held that office honorably and well for four years. This is Mr. Eckhart, who succeeded him, this is now our president, Mr. Thomas Kelley. (Mr. Randolph then pointed out

FIG. 256.

the other members of the Board.) Gentlemen, this is a body of men who have carried this work forward without stain and without reproach, in an age when reproach attaches to almost every public work.

On that list you will recognize four of the old Board members, Mr. William Boldenweck, to whom the finger of destiny points as our next president; Mr. B. A. Eckhart, Mr. Thomas Kelley, and Mr. Frank Wenter, comprise the members of the old Board, and

FIG. 255.

the other five were elected nearly two years ago. Fig. 255 is the seal of the district.

(See map and profile of the Sanitary District, Vol. I., No. 2, 1896.) In this profile, the portions which are shaded very dark are the rock sections, and the light shaded portion is the glacial drift. This shows also the profile of the Des Plaines river.

While it is necessary that we should do a very large amount of work in the Chicago river, deepening and widening it, yet the main channel, as we call it, begins at Robey street and follows down the Des Plaines valley through to Lockport, where it discharges into the Des Plaines. It was necessary, before beginning this work, that we should do considerable preliminary work in the Des Plaines valley. The river from which the valley takes its name is one of those streams which at times has a parched and dry channel, and at other times it rolls like a mighty torrent down the valley. That river had to be trained and taken care of. We had to build thirteen miles of new channel and nineteen miles of levees before the divorce between the sanitary channel and the Des Plaines river was completed. But after a few more months they will make it up and come together at Lockport.

Fig. 256 is Chicago of 1892, quite different from 1812. Each one of those dots represents a population of five hundred people. This is our population map. One of our other maps had indicated upon it in different colors the kind of diseases which prevail in the various districts. That we call our vital statistics map.

Figs. 257 and 258 give a view of the cross sections of American canals and noted foreign channels. The Manchester Canal has the largest cross section. This canal was six years in building; they excavated about 50,000,000 cubic yards of earth and rock,

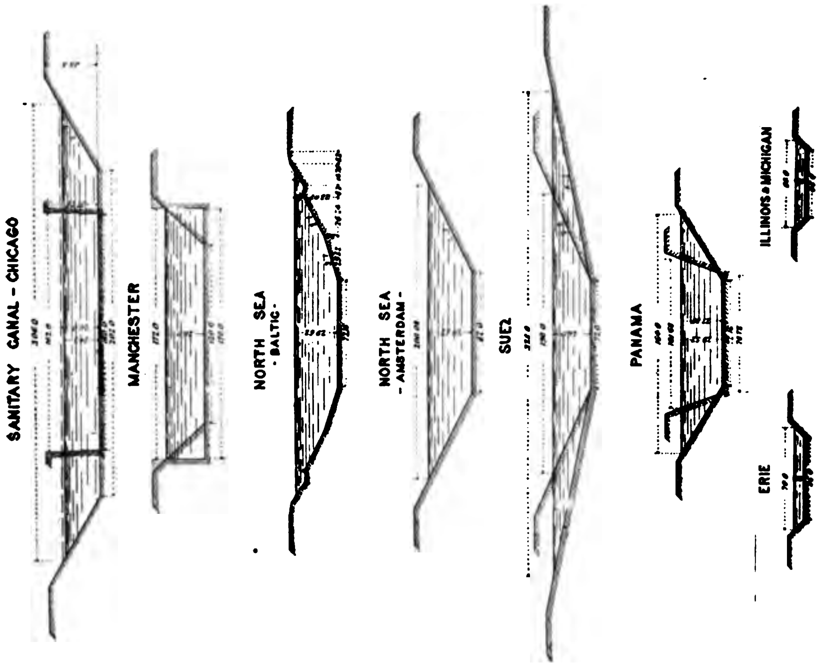


FIG. 258.

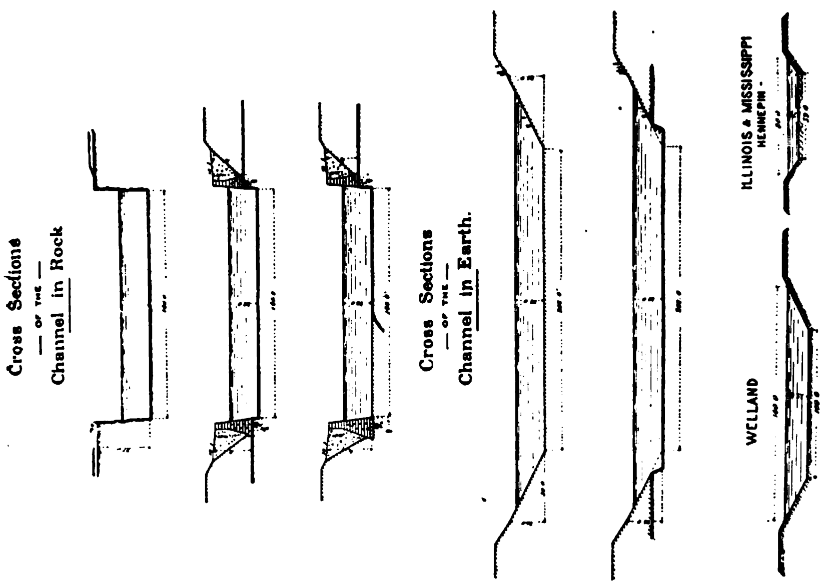


FIG. 257.

FIG. 259.

and the cost of the work was $77,000,000. Then the Suez Canal, the width of which at the bottom is only 72 feet, built at a cost of $100,000,000. Then comes the Nicaragua Canal, which is to be, we hope; then the North Sea Canal, and the Panama Canal, which

FIG. 260.

may be, and the Corinth Canal, which is. The Corinth Canal was eleven years in building, is three and one-half miles long and cost $15,000,000.

American canals. At the top of the cut is the cross section of the Sanitary District Canal. Then we have the Illinois and Michigan Canal; this is the Welland Canal. Here is the Erie; here is an Illinois and Mississippi Canal, which is known as the Marine Staircase and also as the Hennepin.

With Fig. 259 we will start down our channel. We enter upon our journey at Robey street in the city of Chicago, near the intersection of Robey and 26th street; here a connection is made with west fork of the Chicago river. The first two sections, O and M (O is the section next to Chicago), were intended to be left as dredging sections. Section O has been nearly completed, by dredging. Section M, owing to difficulty in securing right of way from the railroads, has been excavated in the dry. Had the excavation from these two sections all been deposited in one volume, it would have made an island of 96 acres in sixteen feet of water.

Figure 260.—Here we come to our eight-track bridge, which is just west of Western avenue. This is a temporary structure; those girders are 80 foot span. The permanent structure as we have designed it is an eight-track draw-bridge, 410 feet long and 116 feet wide; the weight of the structure is about 7,500,000 pounds. We have on this channel seven railway bridges, six of which are double track bridges, and this one eight-track bridge and seven highway bridges. Our bridging is in charge of Mr. William M. Hughes, a member of the Western Society of Engineers. In fact, the influence of the Western Society of Engineers is seen in almost everything that is going on in the Sanitary District.

We now come to the different methods of excavations.

FIG. 261.

Fig. 261 shows the method that has been known to railroad contractors from time immemorial almost, the plow and the wheel scraper.

Fig. 262.—This is a scene on Section I. The machinery illus-

FIG. 262.

FIG. 263.

trated here is known as the Heidenreich Conveyor. This machinery was first introduced, however, by a contractor named Wright, who used it on the river diversion. Heidenreich took

hold of the idea, developed it and made a success of it. As you see, it is an incline with a tipple at the top, and it is being connected with the channel by a trestle with a double track laid on it. There are two cars worked upon these tracks. As one is being loaded, the other is being unloaded with the hoisting machinery which is carried on platform attached to and moving with the incline. As soon as one car is loaded, they hoist it up and the empty car passes down. The car is drawn up on the incline on to the tipple until the weight of the car passes the center of gravity, then it is dumped and returned to the channel to be re-loaded. This whole trestle and incline is moved by a capstan just as houses are moved. I have watched the operation many times, and the movement of the width of the device is made in about three minutes. This was a very successful and economical method of handling material.

Fig. 263.—This gives a different view of the same plant, showing the tracks on the incline and the car in the act of tipping. Here is a steam shovel, there are the inclined tracks leading right down to the tipple.

FIG. 264.

Fig. 264 is a car at the top of the tipple just passing the center of gravity. As soon as it passes beyond that it tips of its own weight.

Fig. 265.—This shows a detail of the tipping apparatus. Here you see a platform ten feet long, pivoted right at the apex of this frame, and as soon as the car reaches it it dumps automatically and then there is a counterweight attached to this cord shown which rights it as soon as the load is taken off, and throws the

FIG. 265.

FIG. 266.

car back into place, so that it runs down the incline to the shovel again.

Fig. 266 gives a view of the half-completed channel on Sections I and K. By this method they excavate progressively parallel with the channel as they do the work, taking the material out next to the sides first and the core last.

FIG. 267.

In Fig. 267 we come to another very successful method of handling material. This is known as the Christie & Lowe method. It differs from the Heidenreich method in this: The excavation is by steam shovel and loading into cars, as before, but the cars, instead of being drawn up on to a tipple, are drawn up on to a bridge which travels parallel with the channel. The supports of this bridge are mounted upon parallel tracks like a railway. The car is hauled up and dumped and that operation continues until the material nearly touches the under chord of the bridge, then the machine is moved forward again. This method was used by Christie & Lowe on their two sections. They first

FIG. 268.

took off the top soil by the use of wheel scrapers and plows, in the ordinary way, then they built two of these bridges side by side, right in the center of the work on the north side of the channel, put in two steam shovels side by side and began their work, taking out the half depth of the channel, the machines moving away from each other as they worked. As soon as sufficient space was cleared in the center of the channel, they erected two more bridges on the south side of the channel, and took out the lower half just as the first two outfits took out the upper half.

Fig. 268 gives an end view of the Christie & Lowe system.

FIG. 269.

There is the steam shovel, there is the car. Those cars hold eight yards. There is a double track for only a portion of the way. There is a gauntlet track on the bridge, and a frog midway

FIG. 270.

up the incline, so that one car passes the frog and gets on the double track before the other starts up, but there are no switches to be thrown.

In Fig. 269 we have another view showing the arrangement of tracks. There is the frog of which I spoke and the loaded car entering the bridge.

Fig. 270 shows a steam shovel working in the bottom of that cut. There is the incline and the bridge.

FIG. 271.

Fig. 271.—Here we come to a very interesting and a very unfortunate machine. It is the Hoover & Mason conveyor. There were a great many devices tried upon this channel, and the history of some of them is almost pathetic. Indeed, to a thoughtful man it is pathetic. This machine was the most stupendous that was devised. As originally built it was 640 feet from tip to tip; there were cantilevers on both sides; those cantilevers carried at the ends immense sprocket wheels. This shows the line of the steel track upon which a steel apron traveled; that apron was let down in the channel in a trough, which was just the shape of the cross section of the channel. The apron was composed of steel plates four feet square carried on trunions at the junctions of the plates. The excavation was accomplished by means of plows drawn back and forth by cables operated by steam hoisting machines across the face of the cut at right angles to the channel. When the plow started at the top, the amount of material moved was tremendous, the steel apron was loaded full, and if that rate had been kept up it would have revolutionized excavation. But as they got near to the bottom the machine became less and less efficient, and finally the plow had to be stopped and men put in to dig out the trough at the bottom. They were usually running about thirty minutes and standing still about two hours preparing to move up. Shortly after starting this machine they met with a disaster. One of the cross beams which carried the track on which the apron ran was sawed nearly in two and a shim put underneath it to hold it; but it was not fastened, itljolted out, the cross beam broke and the apron fell down on the atera l bracing, wrecking the machine. It was rebuilt, and just after it

FIG. 272.

started up again there came a sudden hurricane that blew the machine over and wrecked it the second time. It was then re-

FIG. 273.

FIG. 274.

erected, but I am afraid that it was a venture which cost the ingenious men who built it very dearly. As a conveyor it was a complete success.

Fig. 272.—This is a scene on one of the earth sections, steam shovel at work.

Fig. 273.—Here we come to the spillway which is below Riverside, just at the head of our river diversion. This spillway is shown in the picture in flood time. It is a concrete dam capped with stone. The dam is 397 feet long, its crest is sixteen feet and three inches above Chicago datum. Before this dam was built, whenever a flood of 50,000 cubic feet of water was flowing past Riverside, it flowed towards Chicago in the old Ogden ditch, and

FIG. 275.

as the flood increased, the amount of water flowing toward Chicago increased, and very serious lake contamination has always been caused by the floods from the Des Plaines. Our object in

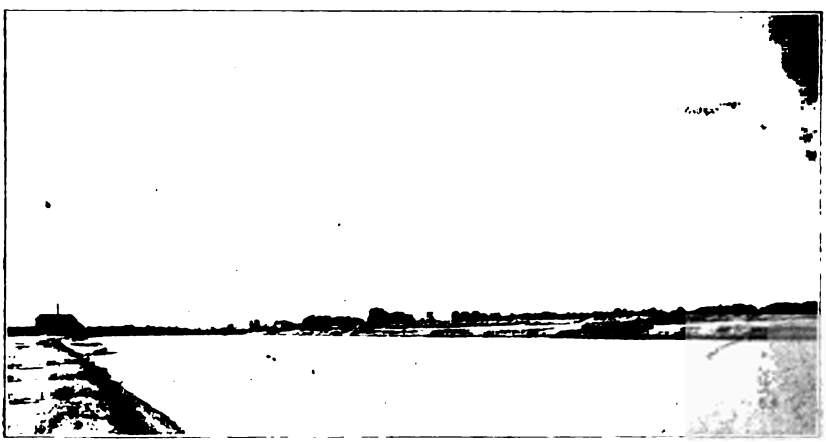


FIG. 276.

building this dam is to prevent the flood waters of the Des Plaines from going towards Chicago. We are unable to accomplish that result entirely until the work through Joliet is completed, but now nothing flows towards Chicago until the volume passing through Riverside exceeds 300,000 cubic feet per minute. Chicago has already felt the benefit of that dam. The flood of 1894 only flowed toward Chicago for sixty-one hours, and then in very limited quantity, whereas it would have flowed toward Chicago for days but for that dam.

Fig. 274 is a scene on Section E, which has had many vicissitudes. This section is now in the hands of its third set of contractors, and we hope that they will be able to finish it.

Fig. 275 is the badge of the Western Society of Engineers, the only badge which I wear and one of which I am very proud.

FIG. 277.

Fig. 278.

Fig. 276.—This picture gives you some idea of how the Sanitary Channel will look when it is full of water. This is Section E when it was flooded out in 1894. There are some people who think that engineers do not know what they are talking about when they fix high water marks. The contractors of these sections believed as little in the high water mark of the engineers as the scoffers did at the time when Noah predicted the flood, but the high water

Fig. 279.

FIG. 280.

rose to the mark and filled the channel and cost the contractors some $5,000 to pump it out again. Probably they will have a little more faith next time.

Fig. 277 shows a monument erected to Pere Marquette at Summit. Mr. Guthrie says that this monument is on the site of his encampment when he first went down the Des Plaines valley.

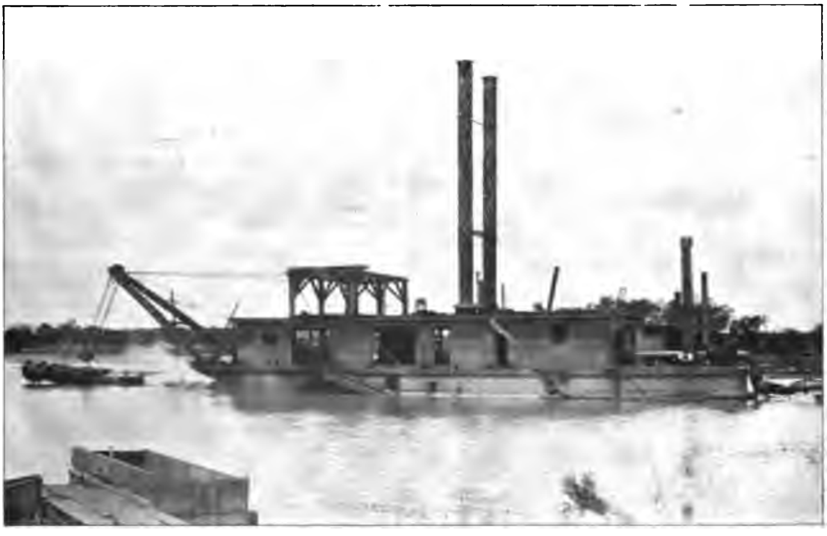


FIG. 281.

Those boulders were brought down for this purpose from the Lake Superior region by the glaciers before Marquette came; they were gathered up by the Chicago & Alton Railroad people and erected in memory of Marquette.

Fig. 278.—Here we have a scene on Section D, a steam shovel loading dump wagons. This was the only section on which this was practiced that I remember. There was a string of wagons, and as fast as one was loaded another one came on. One shovelful was a load for one wagon, and there was a continual round of wagons and it proved a very efficient and economical way of handling the material.

Figure 279.—This is still another scene on Section D during the early stages of the work, giving some idea of the character of the material encountered. Like Jordan, it was a hard road to travel.

Fig. 280.—Here we have a hydraulic dredge, which was operated on Section C. This dredge had a hydraulic eroder and the eroding was very successful, but the catching of it after it was eroded was not so successful.

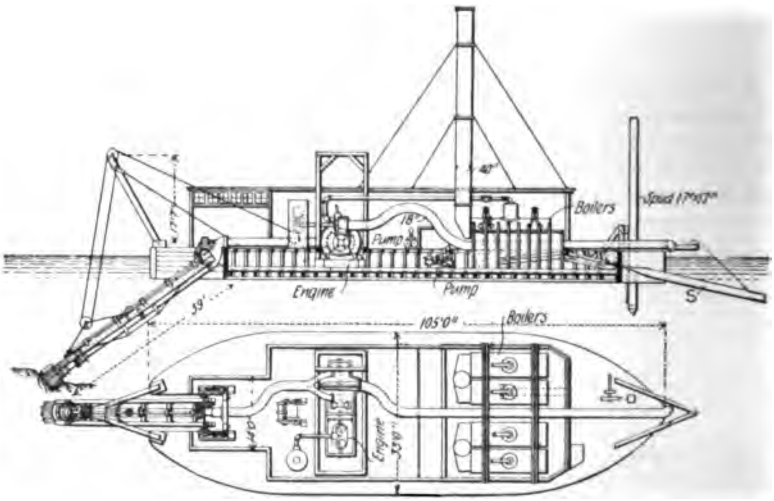


FIG. 282.

Fig. 281.—Here we have a dredge which was very successful When I took charge of this work in 1893, the two most perplexing sections to me were Sections A and B. They lay almost wholly in the bed of the Des Plaines river where the water and the mud together varied anywhere from five to twenty feet in depth. How to handle that material was a puzzler. I had heard of the hydraulic dredge and looked it up and saw one of them in operation and concluded it was the thing for the work, so I advised the contractors who had that section to look into it themselves. The engineers and the trustees never dictated to the contractors what methods they should use. They had the contract and they did it in their own way, but we did sometimes advise. The contractors brought this dredge down, taking it through the I. & M. Canal,

and from the canal into the Des Plaines river. This dredge was so successful that they built another one on the ground of similar type and capacity. The suction pipe at the cutting edge is lifted out of the water for the purposes of the photograph only. This is the rotating cutter which revolved around a twenty-inch suction pipe. The dredge is, as you see, upon a scow which is, I think, 105 feet long by 30 feet wide. On that scow was a battery of boilers and a six foot diameter centrifugal pump connected to a Westinghouse engine of 250 horsepower. The

FIG. 283.

FIG. 284.

spud shown here is the pivot upon which the dredge worked. That spud was dropped into the mud at the stern, and at the bow end there were guy lines thrown out to either shore. There was winding machinery on the front end of the boat which would wind up one guy line and let out on the other, so that the dredge swayed through the arc of a circle, cutting as it swayed. The performances so produced were very satisfactory indeed. The largest output for any one day of twenty-four hours was 11,000 cubic yards. That material was discharged through the pipe shown here, carried about 4,000 feet distant, and deposited in the settling basins. This type of dredge has done very satisfactory work on the Pacific coast, and is now being used in the Mississippi. At Davenport a few weeks since I heard Judge Taylor of Fort Wayne, who is chairman of the Mississippi Commission, deliver a report on that work, and he spoke of the work of a dredge called the Beta, built by the same man who introduced this dredge, Mr. Bates. He said that in two and one-half months that dredge had cut through six of the thirty-six bars on the Mississippi river, making ten and one-half feet of water, that it dredged in that time 8,560 cubic yards per day of eight hours, or 1,070 yards per hour, but that it was broken down a large portion of the time, but the work of cutting over the six bars was accomplished in two and a half months, at a cost of $19,000, or 2 8-10 cents per cubic yard.

Fig. 282 shows a sectional view and the plan of the dredge that has just been mentioned. Here is a suction pipe and the cutting end, showing the way it cuts towards the bottom. There is the

FIG. 285.

centrifugal pump, there the discharge pipe, here the battery of boilers. This shows the same thing in the plans, simply the centrifugal pump and the engines and the boilers.

In Fig. 283 we have a view on Section B after these dredges had done their work and the water had been pumped out. Here is one of the boulders brought down by the glaciers. Mr. Ossian Guthrie can tell you more about those glaciers and boulders than any other man in Chicago or outside of it. By his side stands Mr. Ford, who was principal of the Calhoun school, and who is now dead. These two gentlemen devoted more time and intelligent study to the glacial features of our work than any other men who have ever had anything to do with it, and it was a great misfortune from a scientific side that we lost the results of Prof. Ford's labor by death. He was very enthusiastic and very intelligent in his work.

Fig. 284.—This shows a Bucyrus steam shovel handling glacial drift. Now perhaps some of you do not know exactly what glacial drift is. The definition is given in our specifications about

FIG. 286.

like this: Earth, clay, sand, muck, detached rock, hard-pan, or any other material overlying the solid rock.

Fig. 285 is a scene at Willow Springs, where the earth channel debouches into the rocky channel. Here the channel is 202 feet wide at the bottom with side slopes of two to one. In the next 700 feet it contracts to a width of 160 feet at the bottom with sides vertical or practically so, as there are two offsets that make the top width 162 feet. Of the 29 sections which were put under contract, 24 are now completed and the 25th is practically so and the four others uncompleted are in various stages of progress, so that we may confidently hope to have the whole thing completed by the first of next August, but that does not mean the opening of this channel.

Fig. 286 presents a group of inclined conveyors which were used on Section 1 for handling rock. It was demonstrated there,

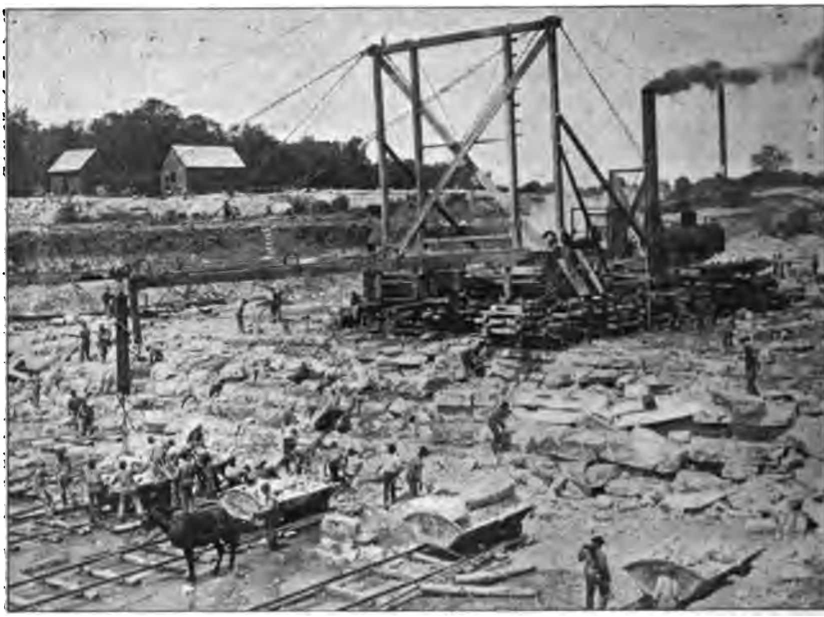


FIG. 287.

FIG. 288.

however, that their mission was not that of rock handlers, but that they were peculiarly suited to the handling of earth, as was done on the other sections.

On that section there is a great deal of experimental machinery.

FIG. 289.

Fig. 287 shows experimentation with air lifts, sections of tracks operated with turn tables, etc. This entire system was abandoned as being too slow and expensive.

FIG. 290.

FIG. 291.

Fig. 288.—This is a scene on Section 2. The glacial drift is being stripped off the rock. The plain surface is the surface of the rock.

Fig. 289 gives still another scene on Section 2, showing the way in which the material was moved by small cars drawn by horses to the foot of the incline, where a cable attached to a hoisting drum drew the cars to the top, where horses were again used and they were thus hauled off to the dumping ground.

FIG. 292.

Fig. 290 gives a view of the tail tower of a cable-way. There were fourteen of these cable-ways in all on our work, and they developed an efficiency which was very remarkable. They were the strongest competitor of the Brown cantilever, which you will see later. These towers were placed about seven hundred feet apart and the interval between is spanned by a 2¼-inch cable on which travels a cage with a series of sheaves in it, over which played several cables passing to the hoisting apparatus. There was an endless cable passing from one tower to another and into the head tower, where the engineer who had charge of the hoisting machinery operated. He worked entirely in the dark so far as seeing anything he was doing was concerned—worked by bell signal. At a given signal he hoisted the skip out of the pit, drew it along until he got a signal to dump, then threw the lever which put the dumping machinery into operation. This device was first put on

FIG. 293.

the channel with no automatic dumping apparatus and was considered a failure, so much so that it was about to be thrown out of service, but one of the contractors associated with Mason, Hoge & Co. invented an automatic dumping machine, and it is now one of the most successful devices in use for this class of work.

In Fig. 291 you see a skip being loaded for the cable-way. There were six or eight of these skips used with each outfit, and it required about forty men to keep the cable way busy. In this figure you see them excavating at one point and hoisting at another. The power of those machines was very great. One single rock which was lifted out by one of them and put into the berm weighed 16,000 pounds.

Fig. 292 is a scene after a blast. Things are rather shaken up.

Fig. 293 is a view in that part of the channel in which the lower part is of solid rock and the upper glacial drift. Wherever this

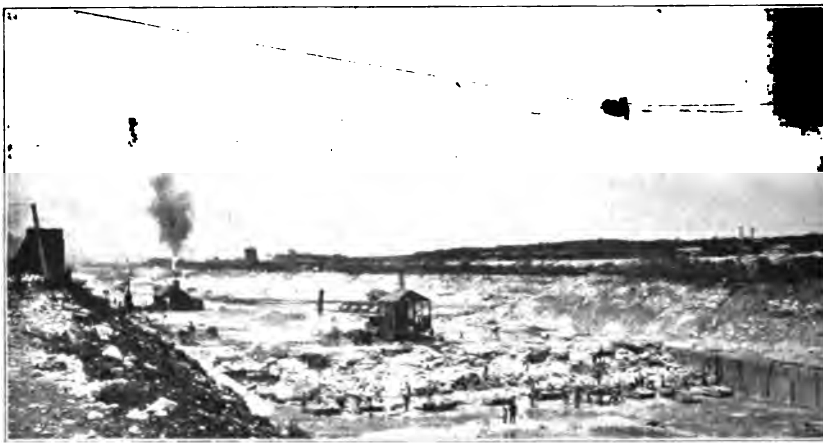


Fig. 294.

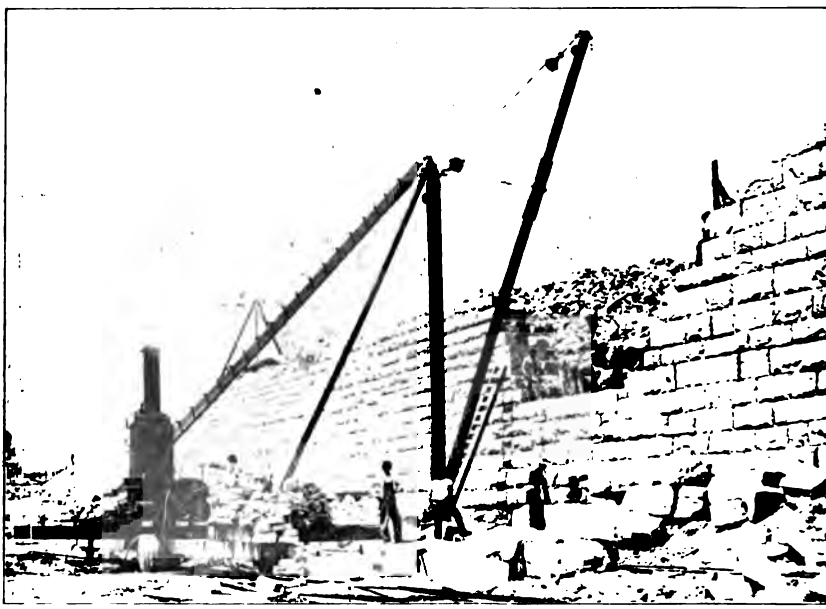


Fig. 295.

was the case a wall was built on the solid rock and carried up to a uniform height of five feet above Chicago datum. Chicago datum was the plane of reference established by the old Illinois and Michigan Canal, and it so happened that it coincided with the low water of 1847; that is, to what is always spoken of as the low water of 1847.

Fig. 294.—This shows the cage of which I have spoken in connection with the cable-way. That cage travels on 2¼-inch steel rope and it carries the sheaves on which the cables for hoisting and dumping the skips are operated. At one time we had on this channel about 8,500 men, and it was a busy scene from end to end. Now it looks lonely enough.

FIG. 296.

Fig. 295 shows the retaining wall. We built 372,000 yards of this retaining wall at an average cost of about $3.25 per yard. The proportions of that wall are, that the width at any point is equal to half the height at that point. The mortar used is the best, one part sand and one part cement. The cements used came almost entirely from Louisville and from Utica. I think about seventy-five per cent came from Louisville.

Fig. 296.—We have had some very peculiar performances on the part of the rock in this channel. Shortly after we got well into the excavation of the channel and had gotten down to grade on Section 10, I received a message from the engineer in charge

that there was a very singular phenomenon on that section, that in places where the rock had been taken out to grade it was then rising. I went down there and found that the rock was moving up in seams right across the channel, sometimes nearly at right angles and sometimes diagonally. It was the first stratum below the grade line which was forced up. Why or wherefore I do not know, and I have never found anybody who could explain it. At first we thought it was the expansion of the rock under the exposure to the sun, but it occurs in the winter just as often as in the summer, so that does not account for it. On Section 14 there is a place today which was at one time 6-10 below grade and is now 8-10 above. Now the case in point is on Section 5. We received word from the engineer in charge about one year after this wall had been built, I think, that there were indications of failure of the solid rock below the wall. There were 13 feet of rock and 14 feet of wall and he said that the rock sounded hollow and that it indicated scaling. At last it grew so bad that we thought something must be done, but we did not know what to do, and it fell out as shown in Fig. 296. Fortunately we got the series of photographs before the final catastrophe came. About seven o'clock one evening, after the men quit work, the watchman heard a tremendous rumbling and grinding and saw the spoil

FIG. 297.

bank rock subsiding, and all of a sudden there was a crash and rush and this wall of 250 feet came into the channel, followed by about 15,000 yards of material.

Fig. 297 is a closer view of this fault in the rock and a portion of the wall above.

FIG. 298.

Fig. 298 shows it after the catastrophe.

Fig. 299 is still another view after the catastrophe. This is one of the unexplained things, but this is hardly the time and place to discuss the theories in regard to it. No defect was discovered in the building of the wall, the mortar was well set and plenty of it, and the failure was in the foundation and not in the wall.

Fig. 300 presents a very handsome view on Section 5, looking west towards Lemont, showing a long stretch, part wall and part solid rock channel.

Fig. 301 shows a steam shovel used for loading the scoops of a cable-way on Section 6.

Fig. 302 shows an improvised cantilever. This is a transformation of a McMyler derrick and inclined conveyor. You will see the original condition of it on Section 9 when we reach that section.

Fig. 303 is to bring out the difference between modern and ancient practice. Here you see the side of the channel which has been cut by a channeling machine, almost as smooth and as vertical as the face of a wall. There you see it blasted out as it would have been without the channeling machine.

Fig. 304 is rather an interesting picture to the student of geology. This is one of Mr. Guthrie's delights. After the earth was scooped off the rock on Section 8, these parallel groovings were found to extend for hundreds of feet. These are supposed to have been made by the glaciers in their passage down the valley.

Fig. 305 brings out man in action. You have heard that the prudent man foreseeth the evil and hideth himself. These gentlemen have heard the signal given for a blast and they are not standing upon the order of their going, but are going at once.

Fig. 306 shows the McMyler high tower derrick and incline as first introduced on the channel by them. This is an excellent derrick and that is a very good incline, but it is taking two machines, two engines and two sets of men to do the work of one, consequently they remodeled it as shown in Fig. 308. These derricks hoisted up the material, then let it down and dumped it

Fig. 299.

FIG. 300.

FIG. 301.

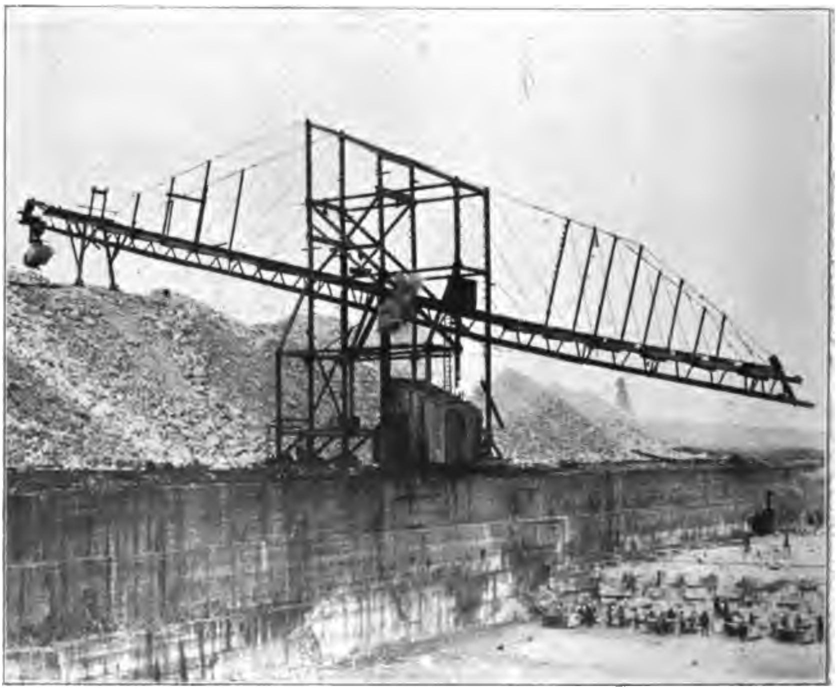


FIG. 302.

FIG. 303.

FIG. 304.

into the car, which is hauled up and dumped as shown, so that there were three operations where one would have sufficed.

Fig. 307 shows an old-time method applied to modern practice. This is on Section 9. The contractor who had that section owned a vast amount of railroad equipment, Pettler cars, etc., and he hated to throw that equipment away, so he used those cars as shown there, hauled them up the incline and then turned them over to the mules to haul away to the spoil bank.

Fig. 308 gives a view of the channel on Section 10 and the rocky spoil bank. In February of 1895, Major W. A. Jones, who then

FIG. 305.

FIG. 306.

FIG. 307.

had charge of the upper Mississippi improvement for the government, came down to inspect this channel. It was a day when the thermometer was about ten degrees below zero, as he expressed it, "A good, brisk Minnesota day," but he thought he could stand it, and as he could stand it I had to. After we had driven several

FIG. 308.

miles and had gotten out and looked at the cut, he said, "Look here, Randolph, this is not a canal you are building, this is a river." When we got down he said, "I have often been the first man to set foot upon peaks in the Rocky mountains which I have named. I want to name this range, this is Cantilever range," and it has been Cantilever range with me ever since.

Shortly before his death, General O. M. Poe visited this channel. When he reached this point he walked out on this bridge and stood and looked toward a railroad trestle about 1,200 feet up stream and he said, "Well, if you take 400 feet off the distance from this bridge to the trestle above and narrow this channel 60 feet, you will have the size of the Sault lock," which was the biggest thing that we were building.

You have heard of the elevating effects of education; there are some other things which are elevating. Fig. 309 is a dynamite blast; it is only a half blast, the rest did not go off, and I want to call your attention to the quickness of the photographic operation. There you can see not only the stones as they are blown into the air, but you can see the shadow of those stones on the face of the rock. At one time we were using eight tons of dynamite a day on this work, and we have used a little over five thousand tons in prosecuting it.

Fig. 310 shows a thorough rock cut. As you see, it is taken out in three loads, or "stopes," as the miners call it. The channel

Fig. 309.

machine is run along the channel on each side, it cuts from twelve to fourteen feet in depth, the rock is blown out between these cuts, and the channeling machines are let down to the lower plane, requiring a passage of eight inches to let it work on a lower plane. The operation was repeated on the second plane, the core blown out and the channel begun on the third plane, so that there are two off-sets in the height of the cut.

Fig. 310.

In this figure is shown a group of Brown Cantilever conveyors at work. These machines I regard as the most efficient which were ever put on work of this kind. Its application is limited; it has not the wide scope of application that the cable-way has, but where the condition is suited, it is a gratifying success. There are nine boxes or scoops used on the face of the cut and forty men operating. These boxes are loaded, hoisted up, run up to the dumping pile, discharged and brought back in very short space of time. I have watched them time and again when it took fifty-two seconds for the round trip, and each trip made a discharge of 7,500 pounds of stone. The scoop and its load weighed about 10,000 pounds.

FIG. 311.

Fig. 311 is another view of this group on Section 10. That was the one on which the work was commenced on September 3, 1892. A memorable occasion.

Fig. 312 shows a better blast than the last one. This is a 1,050 pound blast and it moved from 700 to 800 yards.

Fig. 313 is a view of a drill runner, an Ethiopian as you will see. These men had followed this set of contractors, I think, from Texas to Maine and back again. After they had got to be big machine runners they would not condescend to any other work; if they could not run a machine they would not work, that was all there was about it.

Fig. 314.—Mr. Randolph. This is one of the other men on the job. (Applause.)

Fig. 315 is a view of the curve at Romeo—the spoil bank. At one time there were eleven of these cantilevers in sight, besides any quantity of other machinery. The investment in machinery and plant in this work amounted to about two and three-quarter mill-

FIG. 312.

FIG. 313.

FIG. 314. MR. ISHAM RANDOLPH.

ion dollars and all this plant, when the work is done, is little better than scrap, there is so little demand for it.

FIG. 315.

FIG. 316.

Fig. 316 is still another view of the cantilevers in the vicinity of Romeo.

FIG. 317.

Fig. 317 shows a channeling machine which made this handsome rock channel possible. As you see, it is practically a vertical boiler with a vertical engine attached; the chisel which cuts this channel is attached to the piston of the vertical engine. The whole machine is mounted on a truck and travels back and forth on a track fifteen or twenty feet long, and as the piston goes up and down the machine moves backwards and forwards on this track, cutting about three-eighths of an inch each time it passes over its course. The bit of the cutting tool is shaped like the letter Z. The work of one of these machines is about one hundred superficial or square feet per day.

FIG. 318.

Fig. 318 is a scene on Section 12, showing a fault in the rock, or clay pocket. On Sections 11 and 12 we encountered quite a number of these pockets filled with clay. The clay has been excavated and the cavities walled in.

We have now reached the controlling works. These works are to be the bit which is to curb Lake Michigan's flow towards the Mississippi. They consist of seven lifting gates of the Stony Gate type, with improvements made by Messrs. Johnston and Cooley. In addition to the gates there is one bear-trap dam one hundred and sixty feet long. These gate openings are thirty-two feet each. Provision is made for fifteen openings, but only seven gates are put in at the present time. The other openings are to be used as the capacity of the channel is enlarged. This is our show work. We regard it as one of the best pieces of masonry to be found anywhere.

Fig. 319 is a scene on Section 15, at the end of which the controlling works are located. Section 15 at the end of that channel is of a different shape from any other section on the line. It widens out at its extreme end to 502 feet. The occasion for this

FIG. 319.

is worth explaining. For a long time there was a hot contention in the board as to how the line should be located throughout this portion. Mr. Cooley contended that it ought to be located

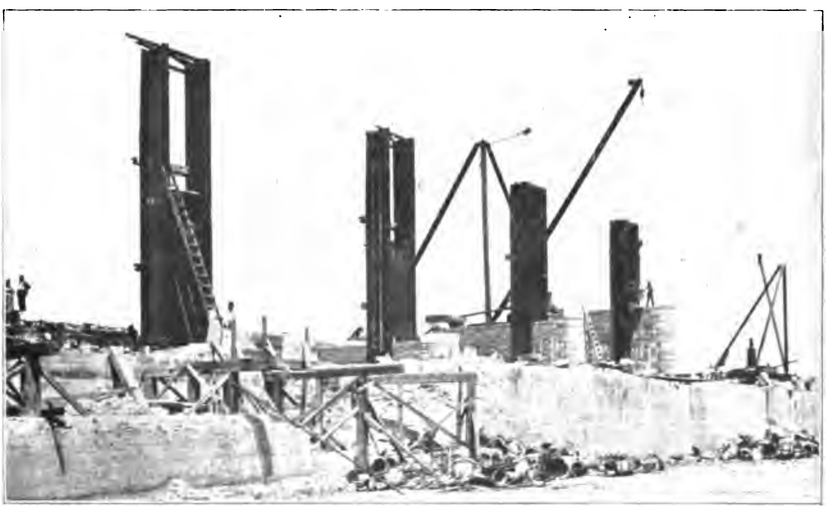


FIG. 320.

FIG. 321.

straight, and the rest of the trustees contended that the stream's location should be followed and that they should curve to the west. At that time nothing was thought of but swing bridges and navigation. The contention waged for a long time and at times was very hot. At last I made the suggestion at one of these meetings that inasmuch as they meant to have a navigable channel and had provided no place for the turning of vessels, that the end of it would be a very good place to make a windage basin to turn vessels in, and that it would be wise to hold the Cooley location for the east side of the channel, and make the west side of the channel on the curved line, leaving the final situation to be determined by future developments. This compromise was accepted, and you will see the results upon the ground today.

Fig. 320 shows the gates and the guides in which the gates are slid. The gates hoist vertically, each gate weighs 60,000 pounds, but it is so counter-weighted and the machinery by which it is operated is so well devised that two men can raise or lower them under pressure.

Fig. 321 lets you see the whole stretch of gates, seven gates in place, and the eight openings for future work.

Fig. 322.—I will explain that bear-trap dam. The bear-trap

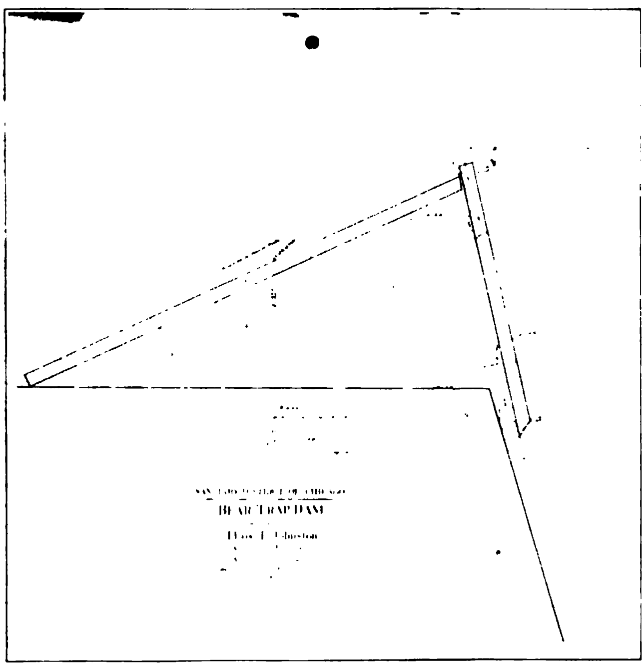


FIG. 322.

was first devised, I think, about 1835, by two engineers in Pennsylvania who were making one of the Pennsylvania streams navigable, I forget which it was—it was a dam which was to be operated by the water itself. It was essentially two great leaves hinged together, one leaf made fast to a heavy foundation on the upstream side—no, the original dam was made fast on the down stream side and the up-stream side worked loose. It worked between bulkheads, and when they wanted to raise the dam they admitted water through conduits provided for that purpose. As they admitted it, the dam floated up and it would assume the position as shown in this cross sectional view, the upper side, the up-stream leaf forming the dam. When they wanted to lower the dam, they closed the inlet, discharged the water beneath the leaf and the dam subsided.

The way it got the name of bear-trap was, that these men when building this device were subjected to a great many interrogations as to what it was. At last, weary of answering questions, one of them said in a hasty way, "Oh, it is a bear-trap," and it has gone by the name of bear-trap ever since.

FIG. 323.

Fig. 323.—Still another view of the controlling works.

Beyond this point the water from the main channel flows into the Des Plaines channel and the work of the district is to prepare this river to receive the flow and take it safely through the city of Joliet. We shall have to expend nearly $2,000,000 in accomplishing this work, and it must be accomplished before the Sanitary channel can be used.

Our present difficulties are somewhat of a legal character. We have to acquire a right of way for deepening and widening the

FIG. 324.

river so as to make it safe to pass the large volume of water which we are to contribute to the flood water of the Des Plaines through the city. We started in, I think, with 150 condemnation cases there; we believe the property owners banded together against us to secure exorbitant prices for their property; up to the present time only two of these cases have passed through the courts. I think in the first case the owner demanded about $245,000 to start with, and the court awarded $71,000. In the other case, which has been settled, the demand of the owner was $50,000 and the jury awarded him $18,000. We are now trying to get a change of venue from Will county to some other county, because we do not feel that we can get fair trial in that county. I estimate that there is about fifteen months of actual work to be done before this channel can be used, and whatever delay we encounter from legal or other causes will add to that period in figuring upon the time that this work can be made available.

The volume of excavation of this work amounts to 40,475,831 yards. In trying to convey some idea of what this volume meant, I once figured up what it would amount to if loaded on railroad cars, and I conceived the earth girded by a railroad at the equator and material loaded in the cars, 40,000 pounds to the car, forty cars to the train and each train with a locomotive and caboose attached to it, and these trains so loaded would

encircle the earth and overlap 174 miles. This material would make nearly thirteen pyramids the size of Cheops.

There have been but few humorous things in connection with this work, and I have but one stock anecdote which I insist upon telling before I allow this audience to go home. I think it was in 1893 that the Western Society of Engineers entertained the American Society and other visiting engineers and took them down to the Sanitary canal by way of entertainment and instruction. At the proper time of day a very prodigal lunch was served, and the visitors were not allowed to go dry. At the close of the entertainment President Metcalf expressed the thanks of the American Society of Engineers for their entertainment. One of the foreign engineers, from Warsaw, the home of Thaddeus, climbed up on the rock, struck an attitude and said: "No one has asked me to speak; I speak for myself. I thank you for this magnificent excursion. This is one grand enterprise. It gifes us ze pure water; wisout ze pure water we cannot lief; wisout ze pure water we cannot have ze goot beer and wisout ze goot beer we cannot have ze magnificent excursion." Gentlemen, I thank you.

XXII.

THE RESTORATION OF THE WATER SUPPLY AT SAVANNAH, GEORGIA.

By Thos. T. Johnston, President W. S. E.

Read December 22, 1897.

In the absence of any other paper, the Chair has undertaken to relate some few experiences he had during the last spring in connection with the water works at Savannah, Ga., the principal subject of discussion being the restoration of the water supply at Savannah.

Steps were taken there last spring to restore what appeared to be a decaying artesian water supply. In order to understand more fully the nature of the decay of the water supply, and the nature of the restoration, it would perhaps be well to outline the general nature of the water works now existing at Savannah.

The city of Savannah had been supplied with artesian water previous to 1890 for some six or eight years, and they had reached a point where it appeared they were not able to increase the supply, and what supply they had did not meet the existing requirements.

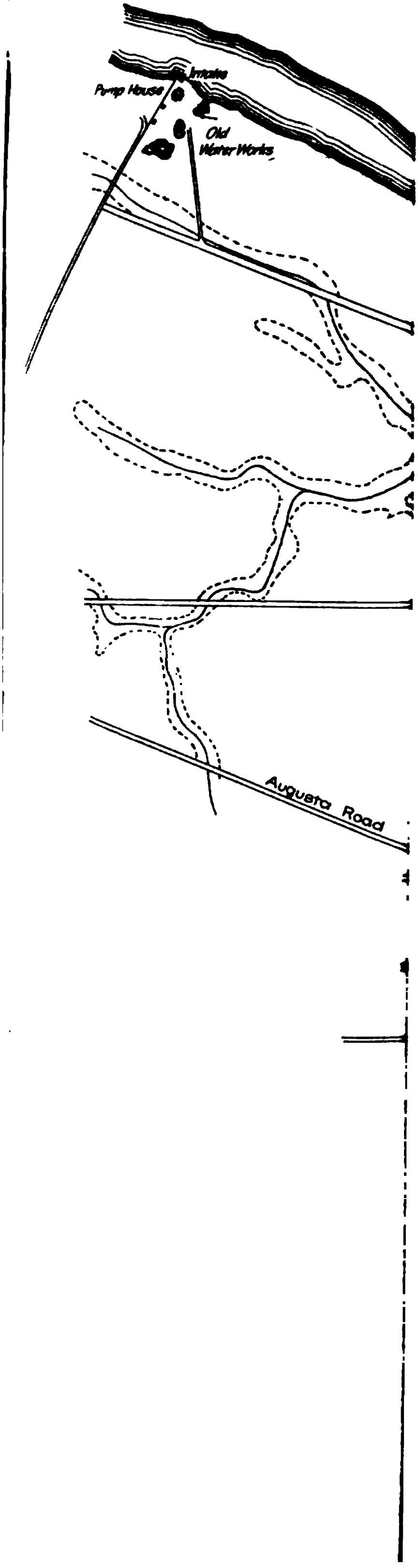
Referring to map of Savannah, Fig. 325, it may be said that the city lies in a parallelogram at the south bank of the Savannah river on a plateau elevated about 40 feet above the mean tide. At the immediate west is an old rice plantation, levees along the river bank preventing periodical overflow thereof. At a point two miles northwest from the central part of the city on the Savannah river was located the old water works, so-called, being an artesian supply and river supply which existed previous to 1890, and as a matter of fact, for some time afterwards. At these works were twenty artesian wells, the distribution of which was very irregular and entirely within the space of a ten-acre lot. The state of affairs in 1890 seemed to require an extension, or at least an improvement of the water supply, and an examination followed in the spring of that year. Among other things, and a point which I would call to your particular attention, the pumping from the artesian well was stopped at a certain time and the supply at that time taken entirely from the river, and the elevation to which the water rose in the wells while they were not pumped was noticed to be 23 feet above mean tide.

The main pipe line from the water works lay across the country from the works to the city. The amount of water that was available at these wells at the time of examination was six million

gallons a day. In the course of the investigation as to what was best to do to improve the water supply, a number of wells bored in the vicinity of the city were examined. The city had bored an experimental well about 1,500 feet deep, shown on the map at the location marked Springfield well. At a distance of about four miles south from the city was another well; at a distance of eight miles south was still another well. There were several wells scattered about the city, some of which had been bored a number of years, but which had ceased to flow and from which not much water was taken. Toward the ocean a distance of 18 miles was a well at a place called Tibee. It was noted among other things that the tide seemed to have an influence upon these wells, not a great influence, but it would be found that they would rise and lower with the tides. That was particularly the case with the well close to the ocean. Account was also taken of the fact that along the coast from Savannah southward through Brunswick, St. Augustine and even farther south, there was an abundance of artesian water, the character of the water being all the same, and what was more encouraging for improving the artesian water supply was the fact that the water was of the same character as that which flows from the Suwanee Springs in Florida, where a river has flowed from the ground for ages. The series of wells having similar characteristics, it seemed that the supply from which the Savannah supply was derived was the same as that creating the Suwanee Springs.

In this connection the interesting fact was noted that the artesian supply at Charleston was quite radically different from that at Savannah, and some explanation of that fact was sought. At Savannah the rock is found at a depth of about 270 feet, and from that depth down to the 1,500 feet to which the Springfield well went, the rock continued. At Charleston they did not meet the rock; the wells are in more recent formations entirely, to a depth of 2,000 feet to which they have bored. The explanation of this seems to be thus: If the outline of the coast north and south of Charleston be noted, then it may be said that the rock ledge which is 250 feet under Savannah bends back into the country, indicating that in geological times at the back of Charleston was a great bay and that it became filled with more recent deposits which were quite shallow at Savannah. It is highly probable that that formation accounts for the great severity of the earthquake at Charleston, the thick layer of soft material under Charleston having shaken much more radically than the thin layer at Savannah; at least, that is the way the people of that part of the country feel about it.

Another important feature in connection with the improvement of the water supply was the fact of fresh-water springs at sea along the coast, especially off Florida. It is stated that off the coast at Jacksonville it is possible to obtain fresh water at quite a distance from the shore, indicating that there is a continuous layer of fresh water under the sea. These waters are so widespread


Intake
Pump House
Old
Water Works
Augusta Road

that they produce flowing wells whenever the same are bored near the coast, and the fact that these wells are influenced by the tide more or less, gives evidence of the continuity of the water-bearing stratum. I cite this fact particularly, because it has a bearing on the question of the restoration of the supply at Savannah, which will appear presently.

In casting about for a particular plan by which to improve the water supply, it was found that a long connecting pipe-line would have to be laid, and the old wells were so scattered that they could not be used conveniently without considerable expense; and, furthermore, a pipe-line dividing the city in half, feeding to either direction, would be preferable to one terminating at the north side of the city. It was finally decided to locate a new supply out by the Springfield well, originating at a point on what is called Styles avenue (a highway shown in Fig. 325), which extends for nine miles without crossing any pronounced ravines, river or creek. The pipe-line which was to feed the city would lead directly along Gwinnett street and have the effect of supplying the city with a maximum supply, with a minimum loss of head. The new wells were to be in Styles avenue, and twelve were bored, each of them twelve inches in diameter, the depth of the first three being 600 feet and the others being 500 feet, the idea being that ultimately, as the city grew and more water was required, more wells might be bored along this highway in both directions, if necessary going over the nine miles. It is highly probable that if the city should require one or two hundred million gallons a day, it could be secured by this method.

Referring to the map, Fig. 325, conceive the wells to be designated northward from Gwinnett street by the numbers 1, 2, 3, 4, etc., the dots indicating the location of wells 300 feet apart.

These wells were each connected to a conduit, which was also located in the street, as shown, and which conducted the water to a pumping station, also shown. The pipe line running off to the city is shown in Gwinnett street. The method of connecting the well to the conduit was by means of a horizontal pipe in which was a water gate which could be closed with the result that the well would be disconnected from the conduit. The conduit is so large that the quantity of water passing through it moves slowly and with little loss of head so that the level of water in the conduit, or the height of water in each well, would be the same, both varying together according as more or less water was being pumped at the pumping station.

The nature of the wells may be described as follows: Rock was met at a depth of 270 feet; wet sand and clay and material of that kind being passed through until the rock was reached; the well was cased above the rock and then simply drilled through the rock for a distance of about 250 feet. The water-bearing belt was found between depths of 350 and 425 feet below the surface. At the time the wells were bored it was not known at just what level the water was derived, and nobody had ever taken the trouble

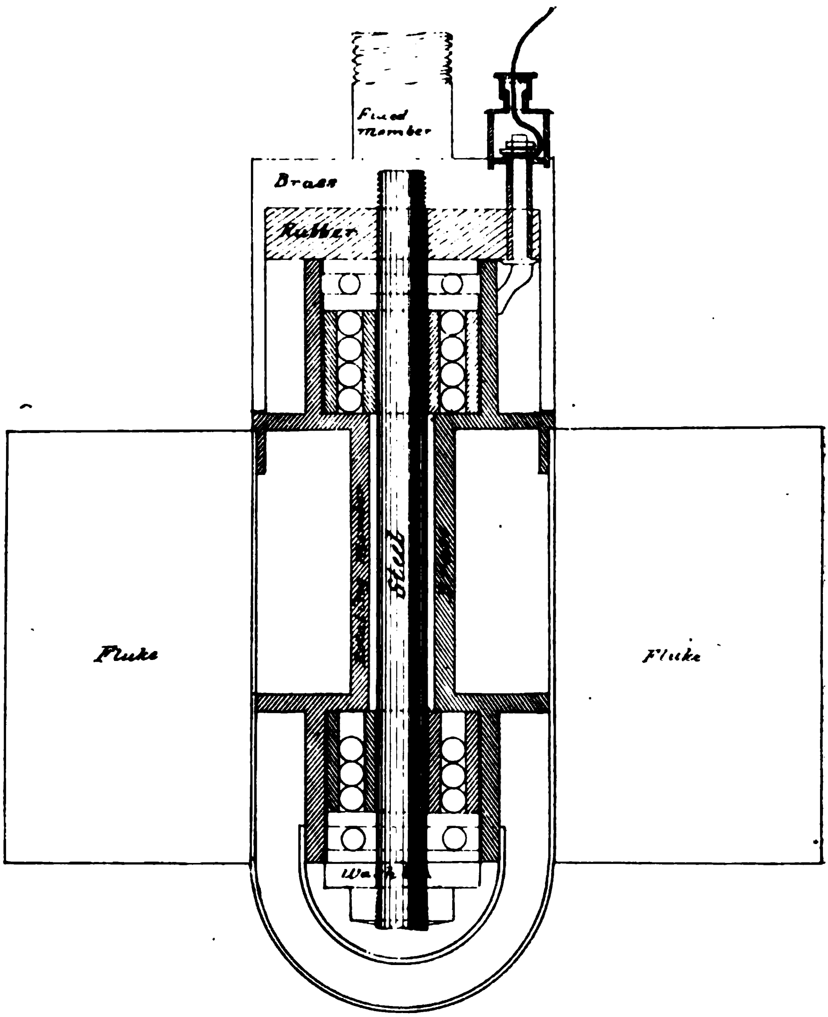
to find out, but in drilling these wells, in the case of nearly all of them, the flow was measured continuously after water was met, a weir being placed at each well and by that means a determination could be made of the points at which an increase of supply occurred and where increase of supply ceased. These observations located the water-bearing belt and showed it to be, perhaps, seventy-five feet wide.

The works were built during '91, '92 and '93, and put in operation first in December, 1892, with seven wells nearest the pumping station being placed in operation. The flow from these seven wells was found, from the time the pumping was started, to be very close to seven million gallons a day, from which it was estimated that when all twelve wells were put in operation a flow of twelve million gallons could be had per day; it actually turned out to be a little less. That was determined in March, 1893.

The work being finished, the wells were not examined and nothing at all being done to them or to the plant in its entirety, through the succeeding years, up to the spring of 1897. During the year 1896, it had been noticed that the flow from the wells had fallen off quite materially, and it caused the people some alarm, thinking that their water supply was going to fail them, and that circumstance led last spring to an examination, on two occasions, into this diminution of water supply to see what it meant, and, if possible, to correct it; if necessary, boring more wells, and, if possible, increasing the supply in that manner.

There were, of course, several reasons why this diminution of flow might have existence. One was that the amount of water available in the water bearing strata was falling off, which would of course have been a permanent loss of the water supply. Another was, that since these wells had not been opened for nearly five years, the walls of the wells might have caved in and obstructed the flow. Another cause that might have been in operation would have this character: the rocks from which the water is derived seemed from the boring to be slightly cavernous; the water did not seep out as might be expected in sand rock, nor come out of crevices, but the rock seemed to be sufficiently porous so that the water could flow from these pores to the wells, and if the pores had been obstructed in any way it would have caused the diminution of the flow. Steps were taken to determine which of these causes had existence, or whether one or all of them existed.

The first operation was to take the caps off the wells and sound them. It was found that the depth had diminished from three to ten or twelve feet, but as there was so much of each well below the water bearing belt over and above the ten or twelve feet, it was determined at once that the clogging or choking up of the wells was not the cause of the diminution of supply. To determine whether the diminution of supply was due to obstructions being placed in the passages leading to the wells, it was necessary if possible to remove those obstructions and cause the



Cross Section on axis of Meter

FIG. 326.

original flow to take place. This necessitated the invention of some device to measure the flow of the water in the wells without great inconvenience. It was decided to construct a current meter which could be set in each of the wells and enable the flow to be determined at any time, and any change of flow to be noted.

It was thought that possibly by causing a reverse of flow of the water through the wells, causing the water to pass out through the passages through which it had been in the habit of coming into the well, that any obstructions that might have existed in those passages would be swept back out of the way, and the flow of the well increased. The first thing to do, however, was to perfect a current meter, and there was some reason to have that done quickly.

Fig. 326 is a cross-section of the machine through its longitudinal axis. Figs. 327 and 328 are from photographs of it. Between the cross-section and the photographs perhaps some idea may be formed of the nature of the meter. It will be noticed on the photographs that the part bearing the flukes of the meter lies apart from the moving mechanism, to which this part must be attached when the meter is in action. The cross-section indicates the position of this part bearing the flukes when the whole meter is assembled, the fluke-bearing part being telescoped on the rotating parts within, and being easily removed or slipped on at will. It will be noticed that the fluke-bearing part (see Figs. 327 and 328) is held in position by means of a bayonet lock.

Now as to the central or mechanical part. Fig 326 shows a fixed part at the upper end, a sort of hood, terminating at its

FIG. 327.

FIG. 328.

upper part with a thread designed to screw into a coupling for one-inch pipe. It is made of brass. A steel spindle screwed into the lower part of this hood forms the axle upon which all the moving parts rotate. A rubber disc, which was cut from a pump valve, surrounds the spindle and fits into the interior of the hood, its axis being coincident with that of the spindle. A washer and nut at the lower end of the spindle complete the fixed part of the mechanism, except as to details explained later. The rotating part consists, in the main, of a brass member telescoped over the spindle and separated from it by ball bearings, as shown in the Fig. 326. At each end are end-thrust bearings, against which rest the lateral bearings. Annular brass pieces form a part of this main rotating member, and it is over them that the fluke bearing part is telescoped. A brass hemisphere is screwed to the lower end of the rotating member, the joint being water-tight. The meter necessarily takes a vertical position when inserted in a well. Remembering this fact, it will be seen that water can have access to the bearing only through the space between the fixed and rotating members at the upper end of the fluke-bearing part, and thence upward through the interior of the hood; but the air, trapped in the hood, though compressed, will still defeat the passage of water to the bearings. This feature has an important influence on preserving the rating of the meter, as well as the prevention of rust and entrance of grit to the bearings. The fluke-bearing part has a hemispherical terminus, so as not to oppose resistance to the flow of water.

The writer is indebted to our fellow member, Mr. E. E. Johnson, for valuable assistance in perfecting the details of the metre.

Now as to the method of recording or ascertaining the number of the revolutions of the meter; the device is shown at the upper part of the Fig. 326. First, immediately above the end-thrust bearing, and in the upper portion of the hood, is the rubber disc, about three inches in diameter, already described. The rotating parts rest against it and are electrically insulated from the fixed piece. Passing through the fixed brass hood and through the rubber disc is a gutta-percha tube, as shown in the figure, and through that is a brass rod, the upper portion of which is fitted with threads and a binding screw at which a wire can be attached. At the lower portion of the brass rod is a flat piece of platinum about an inch long and a half-inch wide. Attached to the main rotating member is a platinum tongue supported by a bronze spring, and this passes over the flat platinum at every revolution of the meter. The contact was rather long, and it was found at first, when a little dirt was on it, that two revolutions might be recorded by one passage of the moving platinum over the fixed platinum, but after cleaning it off no trouble was experienced from that source. To insulate the wire at the binding screws and to prevent the passage of water to the interior of the hood of the meter, a gutta-percha cap was attached to the fixed brass part, about as indicated on the figure, and a stuffing box formed at the upper portion of the attached cap, about as indicated, which stuffing box, made of gutta percha, screwed into threads on the larger gutta-percha cap. The wire leading to the recording instrument passed through the stuffing box, as shown. A metal connection from the recording instrument to the fixed part of the meter formed the other limb of the circuit. At Savannah the meter was lowered into the wells by means of metal pipes screwed to the hood, and these formed part of the circuit, together with a wire from the recording instrument to pipes. This arrangement was entirely satisfactory.

The construction of the meter having been made known, the next point will be as to placing it in the well. A frame was made of quarter-inch pipe and suitable commercial pipe fittings, such as tees, crosses, nipples and couplings. Two quarter-inch pipes were each bent to the shape of a long U, about four feet long, and having a width equal to the diameter of the well. These were placed at right angles and secured at their upper ends to the extremities of a cross made up of fittings. An inch pipe, passing through the center of the cross and perpendicular to it, had the meter secured to it at its lower end, so that the meter rested with its upper part close to the cross, and below it. Above the cross the inch pipe had a length sufficient to insert the meter in the well at the desired depth, which was about thirty feet at Savannah. The quarter-inch pipe and the cross served as a frame to center the meter in the wells and to hold it steady. The wells were all twelve inches in diameter and the meter flukes were so designed as to exactly telescope in a cylinder ten inches in dia-

meter, the clearance between flukes and well casing being one inch.

The photographs, Figs. 327 and 328, show three flukes on the meter. It may be interesting to know that three sets of fluke-bearing parts were made: two six inches high, one of which had three and the other four flukes; and one four inches high which had four flukes. All were tried in well No. 1, and the revolutions for a constant flow were respectively 22.2, 21.2 and 28.8. The meter with flukes four inches high developed more revolutions than the one six inches high, as might have been expected, and yet not too rapid. It was therefore the more desirable. The flukes were all plane surfaces so inclined as to cut the cylinder on which they were mounted through one-third of its circumference.

This point having been determined, the next point was to rate the meter. In constructing the works, at the side of the pump house was a wet well, running the whole length of the house, about 12 feet wide and 12 feet deep, and at the outer end of that was built a weir tank in masonry, that proved to be, at the time of rating this meter, absolutely water tight. It is 40 feet long, 11 feet wide and about 10 feet deep below water surface, and about as perfectly constructed a weir as could be desired. A six-inch pipe tapped into the water supply system was led to the end of the weir tank most remote from the weir, gratings placed in the weir tank properly and the water from the water supply was caused to pass over the weir. The six-inch pipe rested on the bottom of the tank and at that level enlarged to a twelve-inch pipe, which was the diameter of the wells, and for which the meter was designed. An elbow served to change the direction of the pipe to the vertical and thence to a suitable height. At the upper end of the twelve-inch pipe was a tee. Water from the water supply main passed through the six-inch and then the twelve-inch pipes and through the leg of the tee into the weir tank and thence over the weir, where it was measured. Inserting the meter in the twelve-inch pipe below the tee, it was subjected to conditions identical with those to be met in a well. The weir used was three feet long and nicely made. All measurements of head were made by repeated readings on a hook gauge in an isolated still box connected to the weir tank by means of a perforated four-inch pipe. The operation of rating the meter was carried on through a number of periods, as long as twenty minutes or more at the same rate of speed, and the meter was taken down several times and the rating tried after that operation and found to remain unchanged. The nicety with which the meter operated is indicated by the results of the rating as shown in Table No. XXI.

TABLE NO. XXI.

Duration of trial in min.	Head on weir in feet.	Flow in gallons pr. day.	Revolutions of meter pr. min.	Gallons pr. day pr. revolution.
20	0.1354	309702	12.16	25469
35	0.193	540300	21.325	25337
30	0.243	762713	30.77	24787
20	0.3047	1066860	42.40	25160
20	0.3592	1357679	53.50	25377

NOTE:—Readings of head and revolutions every five minutes.

The number of revolutions made by the meter at the time of these ratings is a matter of some interest. It varied from a little over 12.16 revolutions per minute and increased to 53.5 revolutions per minute, and it was found that by slacking up the flow sufficiently into the weir we could get it to record as low as two revolutions per minute, and it seemed to work steadily at that speed.

There might be a number of points raised in connection with this meter, bearing on the general subject of current-meters. It is somewhat out of the usual run of construction of such instruments, and represents an extreme very far removed from the ordinary meters. In this case the heavy meter was of small frictional resistance. I think it very much better than the light meters. The attempts in constructing meters often get them very light, but if there is no resistance to the motion other than that of momentum, which can be eliminated, I rather suspect that the heavy meter has some advantages over the light meter.

Now as to the use of the meter. The meter was put in each one of the wells and their flow ascertained, and the flow was found to vary from 293,000 gallons per day in well No. 6 to 713,000 gallons per day in well No. 1. The water being all from the same strata and under the same head, this result necessarily indicated a difference in the resistance offered to flow in the different wells, which might have been natural or unnatural, or might have come into existence since the boring of the wells. I spoke earlier of having put a weir at each well to measure its flow during construction, but as the ground varied some eight or ten feet in elevation through the line of the wells, it was not possible at that time to say what the comparative flow of the wells would have been under the same condition of head, so that the observation made originally as to flow might be misleading as to what the original capacity of each well was; but at the time of these experiments, with the conduit in existence to govern the water-head at each well, of course, the comparison was made under similar conditions for each well. The Springfield well, which I mentioned before, and which was about 2,000 feet distant from the other wells, at this time flowed 1,019,000 gallons. In 1890 I measured the flow of this well, and found it to be 2,500,000 gallons per day.

Without going into full details of the flows of these different wells, which were found to be quite varied, we can proceed with the experiments with the current meter to determine whether we could possibly remove any obstructions from the passages in the rock leading to the wells by forcing water to flow back through them. Well No. 10 was experimented with first. We got a small fire engine out and pumped water back through it for a short space of time, and, in doing this, we shut off the gate which, as previously explained, intervened between the well and the conduit, so that the well would not be connected with the conduit in any way and cause the water to flow back into it. We seemed to get some slight gain in the flow in that well, but the operation was not carried far enough to be satisfactory to any of us, and the quantity of water passed back through was not more, perhaps, than at the rate of 300,000 gallons a day. For convenience, our next move was to well No. 4. Before flushing well No. 4, we found its flow on May 21 last to be 359,000 gallons per day. The flow from well No. 3, at the same time, was 578,000 gallons per day. We had one large fire engine on this well, connecting the hose at the top, and we succeeded in getting 800,000 gallons through that well in a period of four or five hours; then the fire engine was taken away and the gate opened. When we measured the flow from well No. 4 after it was flushed, we found the flow to be 598,000 gallons a day, which was a decided increase. We then put the meter back in well No. 3, just as we had before the flushing, and found that its flow was 588,000 gallons a day, or essentially the same as previous to flushing No. 4. The flow of the well No. 4 appeared to be increased 149,000 gallons a day as the result of the flushing, which was quite encouraging. Well No. 3 was not changed, its flow before and after being the same. While the flushing was in process, we put the meter in wells No. 3 and No. 5, and found that their flow was very radically increased; there was an increase of about 100,000 gallons a day, I believe, showing that the water passing down No. 4, with but a few pounds of pressure, was going through the water bearing belt to the other wells, thus showing the interconnection underground very satisfactorily.

In this connection, to prove the interconnection of these wells in some strata underground, I will say that in 1892, when we first started to pump wells No. 1 to No. 7 inclusive, we noted the elevation of the water in the wells No. 8 to No. 12 inclusive, before we commenced pumping and after. It was diminished in well No. 8 very much, and in No. 9 not so much, in No. 10 still not so much, and in No. 11 a small amount, showing that the influence of this pumping extended gradually from one well to the other.

Having obtained this result on well No. 4, well No. 6 was next operated upon. May 12, before flushing, it was 293,000 gallons a day; May 18, six days afterwards, it was 304,000 gallons per day; on May 18, after flushing, it was 433,000 gallons a day, an increase of 138,000 gallons, a very large percentage of increase. On May

19, 20 and 24 it was about the same; the increase had continued for six days after the flushing of that well.

It seems quite conclusive that the effect of the flushing, the water going back through the passages leading to the wells, had removed something that had interfered with the flow into the wells because the conditions of head governing the flow were identically the same before and after flushing.

Now one other thing which seemed to clinch the matter, and which we did not think of until after all this work had been done was the fact that on April 24, 1890, the pumping of the wells at the old water works had been stopped and the elevation of the water was 23 feet above mean low tide. In last May, a little over seven years after that measurement in 1890, I found that the level of the water at the old works, which were abandoned when the new works were started, was within one inch of what it was in 1890, indicating that the water plane in the vicinity had not changed. That, in connection with the fact that we were able to increase the flow with each flushing, seemed to be quite conclusive that we would be able to restore what was supposed to be decaying water supply. It remained then to be watched how frequently a well would have to be flushed to maintain its capacity, but in view of the fact that there had been five years of flow since their construction, it would seem some time night elapse before they needed re-flushing. To that end we concluded to lay an eight-inch pipe along the surface near the wells and connect each well to the pipe, and connect the eight-inch pipe with the general water supply, so that there would be plenty of water, and when it was desired to flush a well, a man opening the gate can let the water through the wells at much greater velocity than it would go with a fire engine, and at much greater pressure. That is, I believe, the story of the restoration of the water supply at Savannah.

DISCUSSION.

Mr. Boardman: What is the distance between those wells?

Mr. Johnston: Three hundred feet.

Mr. Boardman: Were the wells tapped at the same elevation?

Mr. Johnston: At the same elevation.

Mr. Feldman. How deep did you place the meter?

Mr. Johnston: It was placed about 30 feet from the top; that would be in the neighborhood of ten or fifteen feet below the conduit connection. In some it would be a little further below the connection, because the top of the well is not quite so high.

Mr. Rohrer: How did the quantity of water compare after you restored it to what it was in the wells originally?

Mr. Johnston: Well, we did not at that time carry this process to all the wells. It was simply applied to those noted, but the evidence seemed to be so conclusive that we determined to go ahead with this pipe matter at once. There was, at the time of this examination, plenty of water to supply the city. The amount

of water available was 7,250,000 gallons, while their ordinary uses are only about six million gallons except in cold winter days when all the water pipes are frozen, then 100,000,000 gallons a day would not be enough.

Mr. Feldman: How deep did you place the engine nozzles when you flushed the wells?

Mr. Johnston: They were connected simply to the top of the wells.

Mr. Bley: What is the size of the spindle in the meter?

Mr. Johnston: I recollect it was 5/8 inch. I have shown it on this sketch as 1/2 inch.

Mr. Bley: Does it form the inner part of the bearings, ball-bearings for the side-thrust?

Mr. Johnston: No, there is a sleeve, the inner sleeve and then an outer sleeve.

Mr. Bley: Do you have that hardened and ground?

Mr. Johnston: Well, it is hardened and ground; the balls, the sleeves and the plates are hardened steel.

Mr. Bley: What was the diameter of the core of the vane head?

Mr. Johnston: It was 2 1/2 inches in this case.

Mr. Bley: And the outside diameter of the vane was ten inches?

Mr. Johnston: That telescoped into the ten-inch cylinder. Those vanes were simply plane surfaces. There did not appear to be anything gained by making curved surfaces, as long as they would go around and make a standard rate; that was all that was desired. They were not curved, warped surfaces, like the ordinary propeller blade.

Mr. Randolph: What was the angle of that plane surface?

Mr. Johnston: The vanes took in one-third of the circumference of the 2 1/2-inch cyclinder. The angle of course will vary with the height of the cylinder. I have forgotten what it was with the 4 and 6 inch flukes.

XXIII.

TESTING CEMENT.

A DISCUSSION.

Introduced by Thos. T. Johnston, President W. S. E., December 1, 1897.

I would like to bring before the meeting a matter that came under my notice four or five days ago, a matter of some interest to most of us at least, and it is a point with regard to the testing of cement.

Dr. Pruessing, the manufacturer of the Hemmoor cement in Germany, was in the city and is going over the United States examining, as far as they will permit him, the manufacture of Portland cement, and incidentally he is advocating a new wrinkle in the methods of testing cements that to me was quite interesting. He was in the laboratory of Robert W. Hunt & Co., where I happened to meet him, and he illustrated the point in testing which he was advocating. It was a new form of conducting the test known as the "hot test." His method of procedure was to take a given weight of cement and mix with only six per cent of water, six per cent of the weight of cement, and water added to the cement, barely dampening it. He put the mixture into a cylinder with a metal plate at the bottom and subjected it to a very high pressure. The cylinder he had was perhaps three and one-half inches in diameter and he aims to get the total pressure, twenty-five atmospheres, as he stated, on that area. That has the effect of pressing the cement into a cake about 3½ inches in diameter and about ½ inch thick. That he places on the shelf in the laboratory for twenty-four hours. Then he puts it on a metal plate, perhaps ten inches square or less and about one-sixteenth inch thick, placing that over a Bunsen burner, the cake being immediately over the burner. He places the bulb of a thermometer over the top of the cake and supports the outer end of the thermometer on any convenient rest and lets the temperature rise to 180 degrees Centigrade, which is way above the temperature used in the ordinary hot tests, something like 360 degrees Fahrenheit. When the cake has reached that temperature he commences putting cold water on it, such as you would draw from the faucet ordinarily. His method for doing this is by use of a pipette, holding a gill of water, from which he sprinkles the cake until the water ceases to evaporate rapidly from it. That being done, he allows it to dry out, still over the Bunsen burner, and then he examines it. If there are any signs of cracking in the cake, it is not good cement, and if it is intact and is not affected at all by that process, he thinks it is reasonable to assume that the cement is good. At least there is an absence of those elements which are met in the

cement which tend to make the cement bad. It is a little interesting to know that a prominent manufacturer of cement is not only an advocate of the hot test, but of such a very rigid test as that which Dr. Pruessing is using, where the temperature is raised so high and the cold water put upon it at the high temperature.

The hot test, I believe, is used by all manufacturers of Portland cement, although a great many have maintained that it is not a good test, or a fair test, to subject a cement to prior to using it in any work. A good many engineers view the matter in the same way. It seems to me that in the present state of the manufacture of Portland cement, at any rate, there is very little determined by the tensile strength. The fact that the cement will hold together and show a greater or less strength in seven days is very far from being a conclusive test that the cement is good, or that it should do so in twenty-eight days or even in a year, or in any length of time. Some incident or circumstance varying from that under which the particular specimen of cement had hardened might cause its destruction. I know one instance that has happened in the course of our sanitary district laboratory work that illustrates the point. We had a specimen of cement that developed very great strength in seven days, in twenty-eight days and in three months. It was a specimen which had originally been rather quick setting, so quick setting that it was not used in our work, although we retained a sample of the cement and tested it. We found that a large majority of the briquettes which were broken at the end of three months would entirely disintegrate with a variation of 100 degrees temperature, Fahrenheit. That cement might have lasted indefinitely at the ordinary temperatures.

Now, I do not know of any other way, not even by chemical analysis, that we could have determined whether that cement was a good or a bad cement, except by the use of the hot test, and where such a slight variation of temperature as 100 degrees Fahrenheit would cause its destruction, I think it could hardly be called a safe cement, or that could be put on the market indiscriminately. In cold weather we might want to use hot water in the cement; we might want to put it where a steam-pipe is located, or perhaps in a number of years the elements would decompose, and that might destroy the cement. It is better to have a cement that would stand the hot test, because the hot test develops the fact that there are constituents in the cement that easily decompose under a comparatively small variation of temperature. The tensile strength of a cement does not develop those elements. It may be a very strong cement in seven days, and, without being molested, may go to pieces at the end of the year. We have run across cements of that kind. There is one piece of work that was done in the city of Chicago about two years ago that I know of. It was not on our work; it was on another piece of work; but we happened to get hold of some of that cement and test it, and as far as tensile strength was concerned and its behavior in the

briquettes, it behaved very well. But in the particular piece of work into which the cement went, the concrete disintegrated in the course of several weeks. That particular piece of cement was probably charged with free lime, that hydrated very slowly, or certain aluminates of lime, the silicate of lime having hardened and given the concrete strength before the dangerous elements commenced to act, and when they did commence to act, then the whole mass went to pieces. We all know that free lime, free magnesia and certain forms of the aluminates of lime, in cement, behave a great deal in the same way. Now, those are elements which may not be determined chemically. We know that there are lime, silica, aluminum and magnesia in cement, but the exact forms in which they exist in the cement cannot be determined by chemistry. We know by taking a cement which is known to be good and mixing into it lime that has been formed at very high temperatures, or magnesia, or certain forms of the aluminates of lime, that they are made bad cements. All cements contain the constituents to make those particular combinations. Now, it seems to me that if tensile strength, or the fineness of the cement, or its rate of setting, or even irregularity in rate of setting from time to time, fail to develop these elements, and if the hot test will develop them, why is not the hot test a good test? Why should it not be applied to all Portland cements, particularly those that are to be used in important works—for instance, in concrete under the pivot pier of an important bridge, where you could not get at it to remedy it, if bad? If a portion of a sidewalk should fail, you can get at that and fix it easily enough. There has been a good deal said, one way or another, about the hot test, and a good many have thought it was not a fair test to make, but I cannot quite understand their philosophy.

Specifications have been so often based upon the mere item of tensile strength that a great many have got into the habit of doing so, but if, in the cements now made, they will consider the wide variation in the strength attained in seven or twenty-eight days, they will hardly regard these strengths as indication of the value of the cements. There are certain natural cements which, examined into, will develop the fact that if they are over six months old, or a year old, are of equal value, and yet in seven days they may show quite a wide variation in strength. They may be equally good products, but a good many specifications will reject the one with the lower strength in seven days, and with a great probability I think of sometimes getting the poorest cement by so doing.

A prominent manufacturer of natural cement remarked, in a conversation I had with him recently, that engineers are driving the natural cement makers to a practice which he doubted the advisability of, and it probably led ultimately to a weaker cement than otherwise could be made. It is a fact that in burning the natural cement there is danger of its being underburned somewhat; not enough to destroy their cementicious nature in a short

period of time; not enough to destroy it in a long period of time; but still, being underburned, they will show greater unit stress in a short period of time than if they are more fully burned, and it sometimes happens that they will show cementicious value in a week or ten days that will be entirely absent at the end of the year. That may be the result of calling for high tensile strength in seven days. In natural cement overburning will not destroy the reliability of the cement or the durability of it. It will show somewhat less strength in seven days or twenty-eight days than cement that is underburned, but in the long run will hang together more surely; it will always be a good cement. If it is overburned too much you just add some inert matter to the cement that will not have a deleterious effect in a long time, although it will not be as strong as it would be if properly burned. That suggests the question as to whether or not the engineers are not making a mistake in calling for a high tensile strength in seven days in natural cements. We have one cement, perhaps, that will show seventy-five pounds in seven days; another one that will show one hundred and fifty pounds, and another one that I know shows over two hundred pounds. The manufacturer makes it two hundred pounds because he thinks the engineers like it best, but in comparing some of the work of the cement compared with cement showing lower tensile strength in seven days, it has not seemed to be as good. I asked this particular manufacturer to suggest a specification that would remedy that trouble; he promised to do so, and I understand it will be forthcoming in the course of time. If he keeps his promise I will try to lay it before the society.

Mr. J. B. Rohrer: I wish to make a suggestion as to what might be made to cover that point. According to your remarks, the cement that was underburned gave a higher tensile strength and depreciates gradually, and the one overburned would be a slow-setting cement and would not positively attain the maximum strength that it would if it were properly burned. I would suggest that your specification require a stated rate of increase of strength between seven and fourteen days or seven and twenty-eight days.

The President: It appears to me that that would be a good suggestion if the time could be taken to make such long tests.

Mr. Rohrer: You could produce the same thing if tests were made from one to seven days; that is, you may get a ratio after the experiments were made.

The President: Yes, that might develop a method. I will say that it occurs to me, now the manufacturer of natural cement took kindly to the idea, that it might be well to specify the limits of seven days' strength, say not less than seventy-five and not more than one hundred and twenty-five to one hundred and fifty pounds. A specified high limit of strength, as well as low limit, might be better than to say "not less than one hundred pounds in seven days."

Mr. Rohrer: In that hot test that you speak about, that is, 180 degrees Centigrade, what effect did the water have upon that briquette? Did it show any cracks at all?

The President: No.

Mr. Rohrer: In your experience with the Sanitary District, what proportion of water did you use in making cement briquettes?

The President: That is a matter of some interest. The American Society specifications, which were written some years ago, have called for 20 to 22 per cent Portland cements. but we find in the wide range of Portland cements that are being now made, that if the cements are fairly good the proportion will vary from as low as 15 per cent to as high as 24 per cent to get an even degree of plasticity in all of them. We have run across some of the Portland cements, which of course were rejected, that have taken as high as 36 per cent of water, which is decidedly abnormal. There are factories in the Lehigh Valley, Indiana, Michigan, Dakota, Arkansas, Denver, Salt Lake and elsewhere, and there is just as much difference in the cements as there is in butter or cheese.

Mr. Rohrer: Regarding the practice of using just a small quantity of water and just putting it in as needed, I suppose the idea is that the small quantity will fill the interstices in the cement and will have the same effect as the large quantity.

The President: The idea advanced by Dr. Pruesing is that he asserts that good Portland cement (and I assume he is referring entirely to German cements) will not take up chemically but two per cent of water during the first twenty-four hours. As he makes his water less than 6 per cent, his idea is only to supply as much water as will be taken up chemically.

Mr. Rohrer: According to the test that he makes, putting water on that piece and it not cracking, it looks as if he had attained the best kind of material for fireproof purposes. Being heated to 180 degrees Centigrade and then having cold water applied, looks like the best kind of fireproofing.

The President: It is an extraordinarily rigid test and there are a great many of our American cements that will not stand it.

A Member: Supposing you reverse that test, subject it to intense cold and then put hot water on it?

The President: That would only have the effect of developing, it seems to me, whether or not the cement would resist the sudden expansion and contractions that would develop, due to sudden change of temperature. In heating the cement, they reduce the lime or magnesia or the other decomposable substances to a condition that will enable them to readily hydrate; they will take up water at once and expand, that is, the process is to facilitate; it is a phenomenon that might happen if a cement is one, two or three years old. Reducing the temperature would not have that effect, as I understand it.

XXIV.

THE FAHRENHEIT SCALE, OR THE CENTIGRADE?

A Discussion—December 1, 1897.

Mr. J. C. Bley: There is one thing in the matter of steam engineering that is a source of trouble to some of us, and that is the awkwardness of the Fahrenheit scale thermometer, and I would suggest that the members express their views of the best means to get out of that difficulty. The Fahrenheit scale as now made place the zero thirty-two degrees away from the point which is most convenient to use in calculations. We naturally, in dealing with heat of water, take the melting point of ice, while, as some engineer—I think it was Charles T. Porter—expressed it, Fahrenheit believed that because thirty-two degrees below the freezing of water was the lowest degree of cold that he could produce, it was of necessity the lowest degree that the Almighty could produce, so must be therefore the absolute zero, and consequently he placed his thermometer scale zero thirty-two degrees below the freezing point of water. Well, that is a thing that we have to keep track of in all our discussions of heat, and if there is some way by which we could either shelve the Fahrenheit scale, or move our zero point up to the freezing point, though we retain one hundred and eighty divisions between the freezing and boiling point, we would arrive at a more convenient form.

The President, Thos. T. Johnston: We might shove back the freezing point of water thirty-two degrees.

Mr. Bley: Perhaps that would be easier than getting a new thermometer adopted.

Mr. Ralph Modjeski: I do not see why in that case we should not adopt the Centigrade thermometer that is used so much abroad, principally in France and Germany. That of course only makes the number of divisions between the melting point and the boiling point 100 degrees.

Mr. Bley: The problem is, which can you get the public to adopt? As long as our weather reports are using the Fahrenheit scale and so many other reports are referring to the Fahrenheit scale, the public is accustomed to that. The point is to get some scale adopted that will remedy that defect. Now the Centigrade scale will be all right if we can get it adopted as a common thing.

The President: It seems to me, if we could get the weather people to adopt the Centigrade scale, that the rest would come quite easy. The great mass of people use a thermometer in connection with the weather. Those that use it in the scientific sense are comparatively few, and the Weather Bureau having adopted it,

there would be little else to do than to change the text books. Then the people that have been using the Fahrenheit scale would have to change their way of thinking, they could not help themselves.

Mr. Bley: Then the point comes up, how will you get the weather people to adopt that? I suppose that would have to come through the act of Congress, would it not?

The President: Yes, I presume it would, and that probably comes through politics and it would have to be a matter of agitation possibly to bring it about. It is not physically impossible I should say.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSLATIONS AND PERIODICALS.

SUPERHEATED STEAM ENGINE TRIALS.

By WILLIAM RIPPER, M. Inst. C. E.

(*From Proceedings of the Institution of Civil Engineers, England, Vol. CXXVIII, p. 60.*)

Conclusions.

The trials recorded show that the use of superheated steam opens a wide field for improvement in steam-engine economy. To obtain the full advantage of superheating, the temperature should be raised sufficiently high to secure dry steam in the cylinder throughout admission and up to release, for which purpose the steam should be supplied at a temperature of about 650° F. at the engine. With steam at this temperature used in a simple non-condensing engine, the same power was obtained for less than half the steam required when no superheat was used. It was found from the trials that as the temperature of the superheat in the steam was increased, the increased economy in steam-consumption which followed was also accompanied by a proportional reduction in the extent of the heat-exchange between the steam and the cylinder-walls. With the highest superheats and the highest economies, the heat-exchange became remarkably small, the cylinder-walls approaching the condition of being almost perfectly non-conducting.

The practical difficulties supposed to be associated with the production and use of highly superheated steam may be (in fact have been), satisfactorily overcome. Experience has shown that the superheater-tubes, after long periods of severe work, show no signs of burning, scaling or injury of any kind. With the greatly improved quality of lubricating oils, and with proper attention as to the judicious application of the lubricant at the working parts, no trouble arises in the lubrication of superheated steam engines. Having once obtained highly superheated steam in the superheater, great care should be taken by the use of suitable non-conductors, to maintain the high temperature of the steam in its passage to the engine-cylinders. The best results in these trials were obtained in association with a high range of pressure in one cylinder and a late cut-off. Any cause which tends to increase initial condensation in the cylinder with saturated steam tends also with superheated steam to absorb the superheat, and to neutralize its useful effect in the cylinder. The superheated steam supplied to an engine retains its superheat up to and surrounding the admission-valve; but when it is admitted

to the cylinder, it immediately parts with its superheat to the cylinder-walls. Unless the steam is superheated at least 200° F. above its normal temperature, and in some cases still higher, depending on the number of expansions, it parts with the whole of its superheat to the walls, and the steam in the cylinder is no hotter than saturated steam at the same pressure. Hence, unless the steam is sufficiently highly superheated before entering the cylinder, it is not dry even at cut-off; therefore the fear of difficulty with lubrication in the cylinder is somewhat unnecessary. Superheated steam at high temperatures may be safely and advantageously used in double-acting engines. Many such engines are now at work and in course of construction.

The chief point to be considered in the design of an engine to work with highly superheated steam is the steam-admission arrangements. Evidently, the steam admission valve, being subjected to the maximum temperature of the steam, should be practically frictionless, so as to remove the necessity for concern about its lubrication. The piston-valve without spring-rings, accurately turned and ground to fit a cast-iron bush, is satisfactory for small powers. For larger powers, various types of equilibrium valve gears are successfully employed. The ordinary flat slide-valve is not a satisfactory type for use with a high degree of superheat, unless the pressure in the valve-chest is low.

EXPERIMENTS ON THE BEHAVIOR OF CAST-IRON COLUMNS IN FIRE.

By H. Schuler.

(*Abstract from Deutsche Bauzeitung, 1897, in Proceedings of the Institution of Civil Engineers (England). Vol. CXXIX, p. 407.*)

In consequence of the warehouse fire in Hamburg in 1891 the Senate of the city caused experiments to be made with wrought-iron and timber stanchions,* which were continued in 1895, with cast-iron columns 10 feet 8 inches long, 10½ inches diameter, and 1⅛ inch or ½ inch metal, centrically or eccentrically loaded, with or without fire-proof casing. They were finished with spherical ends and placed upright, gripped by the two halves of an oven, two yards high, swinging on door-hinges and containing twelve gas-burners which emitted flames at least a yard high. A hydraulic press was below the column and its cross-head above it. The oven was furnished with apparatus for measuring heat, etc., with peep-holes and with the nozzle of a fire-engine. On an average a load of 3.2 tons per square inch, with a red heat of 1,400° F., obtained in thirty-five minutes, produced deformation in a centrically loaded column without casing, which showed itself by bulging all round in the middle of the heated part, especially where the metal happened to be thinner; fracture

*Deutsche Bauzeitung, 1895 pp. 274, 290.

occurred finally in the middle of the thickest point of the bulge. If the load was less this occurred at a higher temperature, and *vice versa.* Jets of water had no effect until deformation heat was reached. The casings tried were of Monier structure, of patent "Korkstein," of asbestic silicious marl and of asbestic cement. These had the effect of increasing the time, till deformation heat was reached, from thirty-five minutes to four hours or five hours, with a measurable temperature of 2,000° F. to 2,500° F. The best result gave a casing of asbestic silicious marl, as a temperature of 2,000° F. was maintained for seven hours, and the deformation diagram justified the conclusion that the column might have stood two hours longer. It is the most expensive casing. The greater thickness of metal in the columns had comparatively little effect on the time, but on the whole a thickness not less than 1⅛ inch seems advisable. Ventilation through the column had a beneficial effect. The behavior of hollow cast-iron columns, even without casing, is superior to that of ordinary wrought-iron stanchions. M. A. E.

"THE MOND GAS-PRODUCER PLANT AND ITS APPLICATION."

By HERBERT ALFRED HUMPHREY, Assoc. M. Inst. C. E.

(*From Proceedings of the Institution of Civil Engineers* [*England*], *Vol. CXXIX.*)

Gaseous fuel possesses certain well-recognized advantages over solid fuel; it is easily handled, and its combustion is completely under control, and causes no smoke or dirt. It is also applicable to many cases where solid fuel could not be used, and it is the fuel of internal combustion engines. For these and other reasons the demand for it is rapidly increasing, and it is the function of the gas producers to convert solid fuel into the gaseous state. In a paper read before the institution in 1886, Mr. F. J. Rowan* gave an account of the Wilson, Dowson, Grobe, Sutherland, Siemens, and other gas producers which had been employed up to that time; and papers on the application of the Dowson producer to the generation of gas for motive power have since been communicated to the institution by Mr. J. E. Dowson.† The author proposes to deal with recent advances in this department of industry.

Producer gas was used for furnace work many years before its adoption for use in gas engines; and its application to generating power, which only commenced about eighteen years ago, has throughout been closely connected with the name of Mr. Dowson. His success, and the great possibilities in this field of work, led to the construction of many other producers for power gas, those of Wilson, Taylor, Thwaites and Lencauchez having achieved excellent results. The Dowson producer is adapted to use anthra-

*Minutes of Proceedings Inst. C. E., Vol. lxxxiv, p. 2.
†Ibid, Vol. lxxiii, p. 811; and Vol. cxii, p. 2.

cite or coke, although gas has been made with steam coal, charcoal, lignite and other fuels. For gas-engine work, however, only anthracite or coke are used, and Mr. Dowson's aim is to replace some of the nitrogen in ordinary producer gas, as used for furnace work, by an equal volume of hydrogen. To this end superheated steam is forced with the air through a considerable depth of fuel at a bright red heat. The resulting gas is cooled and scrubbed, and its composition is that shown in Table VI, Appendix I. The principle of the other producers mentioned is the same; but no doubt certain special advantages may be claimed for each.

The Mond producer and recovery plant not only employs cheap bituminous fuel, but recovers from it ninety pounds of sulphate of ammonia per ton, and yields a gas eminently suitable for use in gas engines, and applicable to all classes of furnace work. The difficulties in the use of bituminous slack, which have been overcome by Dr. Ludwig Mond, F. R. S., in perfecting his producer, have been numerous, involving many years of research and continuous experimental work on a large scale. In addition to the chemical problems of the preservation and recovery of the ammonia and the destruction of all tarry matter, two great troubles arise from the caking of the coal and the formation of clinker. Holes or channels are formed in the fuel, and through them the air and steam flow instead of rising uniformly through the fuel, which burns unequally, and varying temperatures result. The fuel also cakes into arches in the producer and the steady downward motion necessary for good work is prevented. The producer becomes blocked and clinkering is difficult; and, in spite of the bold attempts to break up the mass of fuel and clinker by a mechanical agitator, the system becomes unworkable. Even where it was desirable to use gas coke from a neighboring gasworks in producers of the ordinary type, Mr. Hartley, of the Britannia Engineering Works, found the producers clinker so rapidly that the working became a matter of serious difficulty, and at the close of the second day the engines had to be stopped and the fires drawn. Mr. Hartley then added mechanical means by which the attendant could detach all clinker from the lower portion of the interior of the brickwork, and this gear rendered it possible to use the coke for a continuous run of nine weeks. These difficulties were emphasized by Mr. Dowson* in 1893; and still more recently by Mr. Delamare-Deboutteville, in the report of the trial of large single-cylinder gas-engine,† in which he draws particular attention to the Lencauchez producers employed.

Experiments on gas-producers were begun by Dr. Mond in 1879, and the methods by which he had already achieved success were clearly laid down by him ten years later.‡ Besides the use of bituminous fuel and the recovery of ammonia, the Mond process

*Minutes of Proceedings Inst. C. E., Vol. cxii., p. 17, 11,19 et seq.
†The Engineer. Vol. lxxviii, p. 466.
‡Presidential Address to the Society of Chemical Industry, 1889.

is distinguished by the following characteristics: The producer is worked at a much lower temperature than usual, so that the resultant ammonia is not decomposed, and the fuel does not cake and no clinker is make. The low temperature results from, and is preserved uniform by, the large quantity of superheated steam introduced with the air, amounting to more than twice the weight of the fuel dealt with. The greater portion of this steam passes out of the producer undecomposed, but during its condensation its sensible and latent heat are utilized to produce fresh steam for use in the producer. The gas containing the ammonia is passed through an absorbing apparatus, and, although the quantity of ammonia is small compared with the volume of gas, it is so effectually treated that 70 per cent of the nitrogen in the original fuel is recovered. The fuel is mechanically fed into the producer, and the ashes withdrawn without interfering with the regular continuous working. The amount of labor required is small, as no clinkering is necessary, and the fuel is charged in large quantities of eight hundredweight to ten hundredweight at a time. The gas generated is uniform in quality, and, as no tar is produced, the plant can be kept clean, and the gas cooled to any desired extent, without blocking the pipes and valves.

APPLICATIONS OF PRODUCER GAS.

As regards the general problem of gas-firing, it should be stated that where gas has replaced slack firing, 1.1 tons to 1.2 tons of coal in the producers is equivalent to 1 ton of good slack carefully burnt by the old method. While, however, it is difficult to burn slack under the best theoretical conditions, it is always easy to regulate the burning of gas with only a slight excess of air above that theoretically required. For this reason, and because of the more regular distribution of heat when using gas, the working results of gas and hand firing approach much more nearly to one of equality in weights of slack. The question of decreased labor is also to be considered when comparing the advantages. Many of the furnaces in the finishing department of Messrs. Brunner, Mond & Co.'s works were originally slack fired, and, since the change to firing them by Mond gas has been made, a remarkable saving in repairs has been realized. The cast iron pans, under which the flames pass and through which the heat is transmitted, last four times as long as formerly, and the output of a furnace during its life is more than quadrupled.

To show what might then be accomplished in the supply of cheap power, the author takes as a hypothetical example a factory requiring a continuous power of 10,000 I. H.-P., with a Mond producer and recovery plant, erected adjacent to it to supply the necessary gas for the engines. Let the whole of this 10,000 H.-P. be utilized to drive dynamos yielding 7,000 E. H.-P. at the terminals. The cost of the gas generating and recovery plant is estimated to amount to about £20,000, and the gas engines, dynamos, exciters, switchboards, cranes and buildings would be covered by

the additional sum of £120,000, exclusive of the price of the land, which is a variable quantity. If this plant works day and night all the year round, the total expenses are estimated to amount to £35,100, which includes interest on capital at 8 per cent, giving the total cost of one kilowatt hour as 0.184 d, or of one E. H.-P. hour 0.137 d. The case considered is a favorable but not improbable one, as a factory working an electrolytic process might require a continuous power far beyond the 7,000 E H.-P. In most cases the mechanical power, without transformation, would be required at various points of the work, and in such cases the gas would be distributed in pipe mains to the different gas engine stations. The corresponding total cost would then be reduced to about 0.0865 d per I. H.-P. hour.

It must not be overlooked that with the producer plant in excess of the power plant any required amount of gas can be furnished for heating boilers, furnaces, drying apparatus, etc., in the same works, and this at a lower cost than by the burning coal directly. In a large central station there arises a great advantage in having all the gas engines near the producer plant, for then the otherwise waste heat of the exhaust gases and jacket water can be utilized. Even in the best gas engine between 70 per cent and 72 per cent of the total heat is lost in these two sources of waste, and sufficient heat can be recovered from the exhaust gases alone to raise all additional steam at atmospheric pressure required by the Mond producer. A source of economy is thus presented which will reduce the cost per H.-P. hour below the figures given, and, by effecting the evaporation of the sulphate liquors by a direct gas flame action, fuel would also again be saved. These are sure signs that the best possible results are not yet reached.

The transmission of power from the South Yorkshire or Midland coal fields to the metropolis, and its subsequent distribution and supply at a very cheap rate, is undoubtedly to be looked forward to by metropolitan manufacturers, as well as by the present users of electric power. Mr. James Swinburne and Mr. B. H. Thwaite have drawn up a report of this project, and, with the assistance of Mr. Charles Brown, of Messrs. Brown, Boveri & Co., and the Oerlikon Co., Maschinenfabrik Oerlikon, they have found that a selling price to the local distributing companies of 2½d per unit would leave a handsome profit after paying 7½ per cent interest on the capital. In making their calculations the cost of coal, after deducting the value resulting from the recovery of residuals, is taken at 4s 6d per ton, whereas in the Mond process the recovery of sulphate would be sufficient to cover the cost of coal entirely. The advantages to be derived by consumers, taking power from a large central station as indicated, are not measured simply by the reduced cost per unit. Manufacturers can dispense with large and costly engines and foundations; boilers and coal storage sheds are not required, and greater elasticity in the design of buildings can be allowed when

long lines of shafting become unnecessary. In high factories the transmission of power to the upper stories becomes simple, and isolated machines no longer offer difficulties. The dirt and nuisance arising from carting of coal and ashes and the trouble from steam pipes under pressure disappear, together with the anxiety of a possible breakdown of the main machinery; while on the other hand an exact knowledge is gained as to the power each piece of plant consumes, and more machines can be added at will without multiplying boiler and engine power. The cost of repairs, interest on capital, and charges for water and lighting all diminish with the new system, but more important still is the actual reduction in the amount of power required. In several well authenticated cases a saving of 50 per cent of the total power has resulted after adopting electrical distribution to the individual machines.

There is no doubt that a state of things is rapidly approaching when a central supply for power will eclipse in importance the question of central stations for electric lighting, and the far-reaching effects of the movement can hardly be overestimated. It cannot be foretold what will be the ultimate degree of economy realized, but it should certainly be possible to supply every house in London with gas for heating and ventilating purposes, and electric current for lighting, at such prices that no householder would think of consuming coal in an open grate, or polluting the air of his rooms by burning illuminating gas. The atmosphere of London would be relieved of the smoke which makes a London fog so objectionable, for factory owners would be supplied with power at a cost which even the Niagara Falls Power Co. of America cannot reach. Also the expenditure of England in nitrogenous compounds or fertilizing agents, amounting to about £2,000,000 per annum, would, as the system of gas producers became general, be changed to an annual income arising from the sale of the surplus of the sulphate of ammonia in foreign markets.

"THE ACTION OF SEA-WATER UPON HYDRAULIC CEMENTS."

By DR. WILHELM MICHAELIS. Translated and abstracted by WALTER FRANCIS REID.

(From Proceedings of the Institution of Civil Engineers [England], Vol. CXXIX.)

When a saturated solution of lime acts upon the combined hydrates of silica, compounds of ferric oxide and alumina are formed, containing respectively 3, 4 and 5 molecules of lime to 2 of the oxides, and these compounds are united with water in such proportion that at least 1 equivalent of water is combined with 1 equivalent of lime. Hydraulic cements rich in lime must, therefore, during the hardening process, segregate the lime as hydrate. In Portland cement the hardened mass is completely

permeated with crystals of calcic hydrate. The hydrate of the combined aluminate and sulphate of lime (Al^2O^3, $3CaO+3CaO$-SO^3+3OH^2O) has been observed when the compound was dried over sulphuric acid, and the following calculations are based upon this proportion of water, although in practice it must be far greater. Each molecule of alumina present in hydraulic mortar as the hydro-aluminate of lime can form about 12 parts of this double salt, and the hydro-ferrate of lime acts in the same way. The true Roman cements, containing 1 part by weight of silicate to 1.1 to 1.2 parts by weight of lime, are, from the chemical point of view, the best hydraulic mortars, because, during the hardening process, they form the most stable compounds, without unsaturated residues. Such cements are, however, burnt at so low a temperature that they are deficient in density, so that mortars made with them shrink considerably when exposed to the air through the evaporation of the water which they have absorbed. All water exceeding in quantity that required for the formation of calcic hydrate must be considered as water of expansion and is very loosely combined. Hydraulic limes, such as that of Teil, bear a close resemblance to Roman cements, but are even looser in texture. Of the 68.6 per cent of lime in Teil lime, 36.48 per cent only would combine with the other constituents during the setting process, leaving 32.12 per cent of lime in an uncombined state.

Portland cement, having been burnt at a higher temperature, is denser than Roman cement in the ratio of 5 to 3; but from the chemical point of view this cement is also defective, because, even supposing the richest calcareous compounds are produced during the setting process, there still remains an excess of uncombined lime. A Portland cement containing 61.04 per cent of lime would leave 13.79 per cent of lime unsaturated, while one containing 68.379 per cent would leave a similar residue of 29.1 per cent. In the case of a Portland cement of average composition, with 1 part of silicate to 2 parts of lime, 25 per cent of lime or 33 per cent of calcic hydrate would be segregated.

A body containing a substance of such strong chemical affinity as free lime cannot be regarded as stable. The free lime will continue to react until it forms a saturated compound. When the mortar hardens in the air or in water containing carbonic acid, the lime is converted into carbonate; but in sea-water it is chiefly the sulphates which act upon the lime. In the first instance it is the free lime that is converted into carbonate or sulphate, then the very unstable compound with ferric oxide, then the aluminate, and finally the silicate. The formation of the sulphate with two equivalents of water causes a considerable increase of volume, and may destroy the cohesion of the mass. With this formation of gypsum the production of lime aluminate-sulphate goes hand in hand, and this causes an enormous increase of volume, and a total destruction of the cohesion, for this double compound crystallizes with at least thirty, probably sixty, equivalents

of water, and in doing so converts the strongest mortar into a mud, the only parts of which retaining any cohesion being those protected by the formation of carbonate. Good Roman cements resist the action of sea-water well because they only contain enough sulphate of lime to form sixteen parts of the double salt which finds sufficient space for expansion in the pores of the mortar. In such hydraulic limes as that of Teil there is little alumina, and consequently the chief increase of volume is due to the formation of calcic sulphate and not to the double salt. One of the reasons why Teil hydraulic lime has proved more successful for marine work than Portland cement is that the blocks made with it are allowed to harden in the air for a long time before immersion, while Portland cement is generally exposed to the action of the sea-water at once. Even if Portland cement concrete blocks be exposed to the air until a protective skin of carbonate of lime is formed, such a skin cannot attain any considerable thickness, and the chemical reactions to which the destruction of the cohesion must be attributed will eventually take place. In order to ascertain the action of carbonic acid and sea-water upon the strength of Portland cement, a series of experiments were carried out. Two sets of briquettes were made according to the German standard rules, one composed of one part by weight of Portland cement to three parts by weight of standard sand, and the other of one part cement to five parts of standard sand. These briquettes were allowed to harden for twenty-four hours in the air, but protected from carbonic acid, and were then placed in boiled distilled water for fifty-six days, the vessel in which they were kept being hermetically closed. Half of the briquettes were then treated with moist carbonic acid for five weeks, and were finally returned to the closed vessels, in which they remained four weeks longer. When tested, the briquettes were therefore 120 days old. The 1:3 mortar protected from carbonic acid gave a tensile strength of 26.9 kilos per square centimeter, while the briquettes treated with that gas gave 28.5 kilograms per square centimeter (405.3 pounds per square inch). The crushing strength was 309 kilograms per square centimeter in the first case and 338 kilograms per square centimeter (4,806.3 pounds per square inch) in the second. The 1:5 mortar protected from carbonic acid broke at a tensile strain of 14 kilograms per square centimeter (199 pounds per square inch), and, treated with carbonic acid, the strength increased to 16.8 kilograms per square centimeter (238.9 pounds per square inch). The crushing tests gave 112 and 138 kilograms per square centimeter (1,592.6 and 1,962 pounds per square inch) respectively.

In the 1:3 briquettes only 13.3 per cent of the total lime, and in the 1:5 only 24.8 per cent was converted into carbonate. These briquettes being very small, and the conditions for the absorption of carbonic acid favorable, it is evident that even a long exposure of concrete blocks to the air would only cause a very thin film of carbonate to be formed. The whole of the lime was not converted

into carbonate until the mortar had been coarsely powdered and exposed to the action of carbonic acid for some time. Immersed in sea-water, or in a 2 per cent solution of magnesium sulphate, the briquettes which had been protected from carbonic acid soon disintegrated, and even those which had been carbonated were strongly attacked in seven months, especially the 1:5 mortar, although this had absorbed more carbonic acid.

In fresh water the conditions are more favorable, for only the free lime can be dissolved or converted into carbonate. The more lime is dissolved out the more insoluble are the residual silicates and aluminates. The whole of the lime can never pass into solution, although this may be effected on a small scale when carbonic acid is excluded. A well mixed and burnt Portland cement may contain 70 per cent of lime and yet resist the action of fresh water.

The magnesia which is deposited during the action of sea-water upon hydraulic mortar is a preservative agent which tends to close the pores of the mass. It would be more correct to speak of the injurious action of the sulpates in sea-water than to attribute such action to the magnesia salts, although it is true that magnesium sulphate is the special salt which acts in sea-water. The sulphates of lime or of the alkalis, in fact, any soluble sulphate, have the same destructive action; but do not act with the same degree of energy.

The author finds as the result of his investigations that those cements which are richest in lime are those which offer the least resistance to sea-water. The addition of lime or of more calcareous cements to Portland cement mortar is therefore unsuitable, and modern Portland cements of high strength, but rich in lime, are less suitable for marine work than the older cements containing less lime. A mortar containing free caustic lime is as unstable from a physical as from a chemical point of view. By the reaction already explained, great internal strains are produced and expansion and cracking continue, sometimes for many years. All these defects may be avoided by offering to the lime, which remains or becomes free during the hardening process, hydraulic silica or alumina with which it can form more stable compounds. The disadvantage of the efflorescence of caustic alkali cannot be avoided; but as the quantity is small, and it is easily soluble, this caustic alkali cannot endanger the stability of the mortar. In water the alkali is simply washed out; in the air it is only a temporary efflorescence which cannot be washed off.

The addition of milk of lime to Portland cement mortars must be injurious and hastens their destruction. Even in fresh water the advantages of such an addition are only apparent; the excess of lime is easily washed out and the mortar soon becomes porous. Even in two to three years a diminution in the strength of such cement-lime mortars takes place. The action of carbonic acid may come to the rescue, but the chief use of this addition is to make poor mortars more plastic.

In carrying out experiments on the action of sea-water upon cements, it is of importance that the test-pieces should be as porous as possible, otherwise the results would only be delayed. In carrying out a series of experiments with various mortars the author used artificial sea-water, and solutions of calcium sulphate, magnesium sulphate and sodium sulphate. The mortars were moulded in the form of prisms ten centimeters long with a rectangular section of five cubic centimeters. For twenty-four hours the briquettes were allowed to harden in moist air, from which carbonic acid was excluded; they were then placed in the test solutions. The solutions were renewed daily for fourteen days, weekly for three months, and then monthly. One of the mixtures which withstood the action of calcium sulphate best was Teil lime mixed with five parts of standard sand; but all mixtures containing hydraulic silica either as hydrate, or in the form of trass or burnt kaolin, were but slightly acted upon, and remained intact after the lapse of two years.

In a one per cent magnesium sulphate solution similar results were obtained. Neat Portland-cement mixtures, without the addition of hydraulic substances, soon disintegrated, especially in the case of those cements rich in alumina. A Bavarian Roman cement containing 47.2 per cent of lime stood well, while a Bosnian Roman cement with 49 per cent of that substance began to show signs of deterioration. Long before there are visible signs of disintegration through the action of sea-water the tensile strength indicates whether an injurious action is taking place. As porous briquettes are more rapidly acted upon than impervious ones, it is advisable to use a mortar containing one part of cement to five parts of sand, rather than one composed of the 1:3 mixture. A number of experiments were carried out by the author, in which the briquettes were composed of one part of cement mixed with five parts by weight of Berlin standard sand.

SECTIONS OF MASONRY DAMS.

By PELLETREAU.

MASONRY DAMS.

By L. DURAND-CLAYE.

(Annales des Ponts et Chausees, p. 90.)

(From Proceedings of the Institution of Civil Engineers [England], Vol. CXXIX.)

In the first of these articles the author commences the consideration of his subject by the determination of the form of a dam, rectilinear in outline, in which the line of resultant pressure shall not fall outside the middle third of any horizontal section, so that no portion of the masonry shall be subject to tensional stress. For this he obtains the well-known formula:

$$\tan^2\Theta = \frac{1}{D} \ldots\ldots (i,)$$

in which D is the specific gravity of the masonry, and Θ the angle between the up and down stream faces of the dam, the up-stream face being vertical.

This section, however, he points out is liable, owing to the possible formation of horizontal cracks, to allow a tensional strain to come on portions of the up-stream face; and any such horizontal cracks will, owing to the existence of this tension, tend to spread into the work, resulting in the final failure of a portion or the whole of the dam.

Mr. Pelletreau therefore proceeds to examine to what extent it is necessary to reinforce the dam in order to avoid this liability to tensional stress; and the formula he gives is:

$$\tan^2\Theta = \frac{4}{12D - D^2 - 16} \ldots\ldots (ii).$$

In a dam constructed in accordance with this formula, the presence of a horizontal crack in the up-stream face will not cause tensional stresses in the masonry (that is to say, it will not tend to increase) until it has extended through nine-tenths of the horizontal section; but the amount of masonry will be increased by from 13 per cent when D=2.5, to 25 per cent when D=2.2. He also gives an intermediate formula:

$$\tan^2\Theta = \frac{9}{12D - 11} \ldots\ldots (iii,)$$

and in a dam of this section the crack can extend over one-third of the horizontal section before the material is subjected to tension. The increase in this case is 8 per cent when D=2.5 and 13 per cent when D=2.2.

He then discusses the possibility of so forming a dam as to prevent horizontal face cracks, containing water under pressure, from extending into the main body of the masonry. This he thinks

only satisfactorily feasible by a system of vertical piers, covered on the up-stream face with masonry arches, so that any leakage through the face would drain away between the piers. He calculates the dimensions of these piers and arches for a dam 98 feet high with a distance of 33 feet between the piers, and covered in from pier to pier on the up-stream side, with a facing of vertical semi-circular arches. The piers are highest on the up-stream side and slope downward on the down-stream side; while in order to steady them in the case of any accident to the arched facings, they are connected across by horizontal arches at intervals on the down-stream faces. Including these cross arches, the author calculates that the cubic contents of a dam 98 feet high on this arched system, and of equivalent solid ones in accordance with equations (i.) and (ii.), would be 378, 395 and 443-490 cubic yards per linear yard respectively, the last two figures depending on the density of the masonry.

There is a sheet of drawings showing the 98-feet dam referred to above on the arched principle proposed, and also eighteen small explanatory diagrams in the body of the text.

The second paper is a short note, with three explanatory cuts, showing how *vertical* cracks in the up-stream face of masonry dams will, by admitting water under pressure, have a tendency to spread into the work, and may extend in the direction of the length of the dam, thus causing partial instability, endangering the safety of the work as a whole. R. B. M.

THE EXISTING METHODS OF CLARIFYING SEWAGE-WATER AND THEIR RESPECTIVE VALUES.

By Dr. Marx.

(Deutsche Vierteljahrsschrift fur offentliche Gesundheitspflege, 1897, p. 260.)

(*From Proceedings of the Institution of Civil Engineers* [*England*] *Vol. CXXIX.*)

The various chemical and other processes for the treatment of sewage are discussed, and the objects to be attained are examined. At the present time most of the authorities are agreed that the best results can be secured by means of irrigation, and the importance of the process of nitrification, due to the "action of a living ferment of the bacteria family" present in the soil, as pointed out at an early date by Mr. H. Robinson, is insisted upon. The opinions of numerous authors are cited, and, from the point of view of the purifying power of rivers, attention is called to the part played by minute vegetable organisms, the action of which upon the polluting matters present is parallel to that of the bacteria in the soil. The lime process is explained, and the results attained by the use of this precipitant at various places are examined. A brief account is given of Scott's cement process, as also of the black-ash treatment of Hanson, and the systems advocated by Whitthread, Bird, Stothert, Anderson, and others.

Passing on to methods of treatment where lime is not employed, allusion is made to the ferrozone-polarite process and the methods of treatment involving the use of electricity.

The author sums up the results of his investigations in a series of eight conclusions, and he states that, while no absolutely perfect system of treating sewage is yet known, the best plan is, undoubtedly, that of irrigation on suitable, well-prepared areas. Simple deposition in tanks, although the most imperfect of the modes of dealing with sewage, is advisable as a preliminary to the discharge of raw sewage into rivers. Both physical, chemical and biological agencies play their part in the self-purification of rivers, but the most important factors are the species of algae devoid of chlorophyl. Special advantages are attained by the Rothe-Rockner process, and the system introduced by Hulwa destroys all germs. The ferrozone-polarite process has proved itself to be the best of all systems which do not involve the use of lime. The treatment by means of electricity has not hitherto answered the expectations of those who anticipated that this process would afford a convenient, effective and cheap method of clarifying sewage water. G. R. R.

EUROPEAN SYSTEMS OF HOUSE-HEATING.

By J. L. Saunders.

(*From Engineering Magazine, January, 1898.*)

There is no doubt that America is now far in advance of Great Britain in its systems of heating apparatus, and the materials and methods used in their installation. Many years ago the mode of heating was as crude in America as, I am sorry to say, it often is now in Great Britain; but, as time went on and the demands became greater, natural competition proved to be, as always, the greatest producer of improvements; every keen competitor was anxious to have the latest device, style, system or material to assist him in obtaining a contract. For example, the hot-water or low-pressure steam boilers generally employed in America are, as a rule, far in advance of those in general use in Great Britain. This great advance has come about within the last fifteen or twenty years.

One of the principal points for which the manufacturers have striven was to produce a boiler that would give the maximum amount of heat for the minimum consumption of fuel, the cost of fuel being a great consideration in America. And as every manufacturer was anxious to produce the best boiler, it is natural that the questions of grate surface, fire surface and rating of a boiler should have been carefully studied in America. Other points receiving especial attention have been the manner of constructing the surfaces in the boiler so that they will absorb the utmost of the heat of the gases before they pass into the chimney; simplicity of construction; easiness of erection; getting them into the build-

ing required to be heated; cheapness and simplicity of repairs, and facilities for firing and keeping clean. From the combined results of all this study the modern American boiler has been developed. In Great Britain all these important factors in the construction of a boiler seem, as a rule, to be but little studied. The average English boiler seems to be constructed with but little consideration for the amount of fuel it will consume, and its grate and heating surfaces seem to be proportioned, not according to any set rules or ratios, but purely by guesswork. Many a boiler manufacturer of Great Britain, if asked the size of the grate surface or fire surface of his boiler, or its rating in proportion to its grate and fire surfaces, would look in astonishment, and ask the purpose of the question. In many cases, indeed, he could not tell. With but very few exceptions, the boilers made in Great Britain are of wrought iron, either welded or riveted, and are made in one piece, requiring to be brick-set. Almost invariably this setting is done according to the individual idea of each heating engineer or heating contractor. The boiler manufacturer does not have any particular design for setting the boiler bought from him. Thus it may be seen how vague are the statements of the rating of a boiler, as this depends a good deal on how it is set.

Nearly all the manufacturers make the same style of boiler, the only difference being that each has his own name. The only competition is in price. But within the last few years some manufacturers have begun to produce and push patent boilers of their own, using as strong arguments for their special type its advantage in construction, style and heating-power in comparison to fuel-consumption. A few years will no doubt witness vast improvements in the boilers for heating systems in Great Britain. Most of the new boilers put on the market at present are of the American style, and do not require to be brick-set; they are called independent boilers, but they are made of wrought iron.

The British people are somewhat prejudiced against the cast-iron boilers, for just what reason it is hard to tell; no doubt one reason is that cast-iron boilers so far produced in Britain have been cast in one piece, have been very heavy because of the thickness of metal, and may easily be broken because of unevenness of expansion and contraction, as well as unevenness of thickness. It is asserted, also, that if a boiler is of wrought-iron made in one piece, there is less likelihood of leakage than in a cast-iron sectional boiler which has to be put together with many joints. This is a point open to discussion. Although there is this prejudice in England against cast-iron boilers, it is no doubt dying; I have used a number of American cast-iron boilers in recent contracts, and several firms are using and selling American cast-iron sectional boilers in Great Britain today. In fact, there is one English firm that is putting on the English market a cast-iron boiler of American manufacture,

though sold under another name. Although the larger number of boilers in use in Great Britain are of wrought iron, either brick-set or independent, both classes show great variety in type, style, and mode of construction—especially in the arrangement of flues, cross tubes and narrow flues. The greatest objection to the independent boiler is that, as a rule, it has no covering, and therefore is giving out a great deal of its heat where it should not. Indeed, the commonest fault with British boilers is that they are great fuel-consumers.

The low-pressure hot-water system is the one most largely used in Great Britain, but its chief application is to the heating of schools, churches, and public buildings; very few residences are heated in any way except by the open fire-place, although of late years far more of the owners of large residences and mansions are putting in some one of the newer heating devices, using it, as a rule, as an auxiliary to the open grate, which holds its own because it ministers to the natural love of the sight of an open fire and the maintenance of good ventilation. Low-pressure steam is but little used, as it is often considered to give too high a temperature for the heating of buildings. Another reason may be that its installation is not well understood, some very bad results having been produced. The two-pipe system is used, and the principal trouble has been that the returns have not been properly taken care of, with the result that water hammer has run riot. The one-pipe system is but little known, and the British architect is rather a difficult person to convert to new ideas. There are a few firms in Great Britain which are now doing considerable steam-heating, using one-pipe work; and very good work indeed they are doing, for there is no question that, when the Briton goes in for good work, he does the very best. The fan system (or plenum, as it is called in Great Britain) has only of late come into use, and only in large public buildings, but it bids fair to become prominent. It is installed in Great Britain in a manner somewhat different from that prevailing in America; more often than not low-pressure hot water is the heating agent instead of steam. Instead, however, of making one large heating chamber, from which the warmed air is blown through tubes to the upright flues and thence to the different apartments in the building, the heating surface is subdivided, and the small units placed at the foot of each individual flue, and cased in. A brick tunnel leads from the fan around the building (under the ground floor), and from this tunnel the air is supplied to each stack of heating surface and regulated at the bottom of the separate flues. There are, of course, many ways of installing the fan system and of regulating the supply of warm fresh air and of taking out the foul air. Where low-pressure hot water is the heating power, a gas engine is used to draw the fan.

The high-pressure hot water system (known as the Perkins system) was at one time very largely used in Great Britain, but

of late is less often installed. In this system the boiler is simply a coil constructed of very heavy wrought iron pipe and incased in brick work. From this coil are run strong inch pipes with ⅝-inch or ⅞-inch bore. The circuit is generally continuous, with no valves and no means of shutting off any part of the apparatus; the heat must be either on or off for the entire building. In some cases, however, there are several circuits with valves and bye-passes to each circuit. The pipes are put together in a very strong manner, for they have to withstand a heavy pressure. The joints are connected by right and left hand couplings. The joint is not made by tightening on the threads. The ends of the pipe are made one convex and the other concave, and the process of tightening the couplings butts the two ends of the pipe together. The same kind of joint is made with all fittings, and the fittings are all made of wrought pipe of heavy gauge; where bends (or elbows) are required, the pipe has to be bent by the use of a fire. The system is run at a very high temperature, and, as it is entirely sealed up with but a small air-chamber or air cushion, the pressure is very great. The principal objection is the unevenness of temperature, caused in the following way. When the fire is on, the water does not circulate slowly, as in a low pressure system, but stands still until a high temperature is reached, and then goes through the pipes with a rush; as soon as the fire drops, the circulation stops, and the heat soon dies down.

The use of hot-air heating in Great Britain is very small; in fact, about the only system used is the Grundy, and that principally in churches and schools. It is different from the practice in America, which commonly involves the use of a furnace with tin flues.

The systems of low-pressure hot-water heating in use are much the same in both countries, the three principal being the rising system, the drop system and the one-pipe system. In the first, the flow and return are duplicates one of the other, and the mains run side by side, or one above the other, in the basement cellar or in trenches below the ground floor, branches rising from these mains. In the drop system, a main riser is taken to the highest point of the building, and a main run around the top of the building, and from this main are taken drop pipes which supply the heating surface on their way down, the flow and return to the coil, or radiator, being from the one drop pipe; then all the different drop pipes are gathered into a main return pipe below the ground floor and returned to the boiler. The one-pipe system consists of one large main, in basement or cellar, which main is of the same size throughout. Its highest point is at its exit from the boiler, and it has a gradual fall all the way till it enters the return. This one pipe is used for both flow and return, the flow branches leaving the top and the return branches entering at its side.

Although the systems are much the same in both countries, they vary in detail; all three systems have been more fully developed in America. The rising system is most frequently used in Great Britain, the other two systems named being less often met, although I have put in several since my return to England. As to style of work, America is far in advance, but the large demand for heating and the great competition account for the superior quality of American work. The demand for heating systems has been comparatively small in Great Britain, as the country has been satisfied to go on in its old lines; but, as the demand increases, improvements are made, and some very fine systems are now being erected. Indirect heating, for example, which until very recently was hardly known, has been introduced in several large and handsome residences, the work being of the very best class. The indirect stacks are incased in chambers constructed of the finest glazed bricks, so arranged that access can be had for cleaning. The registers are of solid bronze metal of Tuttle & Bailey's best manufacture. Several strong principles which have been allowed to govern the erection of heating plants in Great Britain have prevented the work from presenting the most pleasing effect. One of the most prominent is the prevailing use of cast-iron pipe, heavy and clumsy in appearance; it has to be adopted in many cases for the reason that the water is so bad that it destroys or fills up the wrought-iron pipes in a very short time. This has limited the demand for wrought-iron pipe, especially in sizes more than two inches in diameter; and, as a natural result, the prices of all the larger sizes are very high. No doubt to an American a very peculiar appearance would be presented by a heating job wherein the mains were of cast-iron pipe in lengths of nine feet, with spigot and socket joints caulked together with either rust joint, or red and white lead and spun yarn; nevertheless, a great part of the work in Great Britain is done in this manner; again, much of the heating surface is constructed of coils made of cast-iron pipe, two inches and upwards in diameter, put together in the manner described above. In greenhouse work cast-iron pipe is always used, and, as a rule, the joints are made with india-rubber rings, known as india-rubber expansion joints. Another point affecting heating plants in Great Britain is that comparatively few of the buildings have basements under the whole house; this makes it very difficult to get in mains, and the result is that the mains are made as short as possible, and the different rooms are heated by running long coils from room to room, making long circuits with short mains, to avoid very heavy expense in making channels, trenches, or tunnels below the ground floor. At one time there were but few radiators in use in Great Britain, the heating surface being usually of cast-iron pipe and cast-iron coils; but now the public is beginning to desire them and architects to specify them. But the Briton has little desire for decoration. It is generally his request that the radiators be put

out of sight as much as possible. There is no doubt that the heating business in Great Britain is improving very much, and that the class of work is growing better every year and patterning more after American practice; but no doubt it will be some time before buildings are heated throughout, and each room controlled by a thermostat.

ELECTRIC ELEVATORS.

By PERCIVAL ROBERT MOSES.

(From Engineering Magazine, December, 1897.)

The question of prime importance in elevator design is that of safety. Economy of operation and ease of control are large factors, but, no matter what else may have to be sacrificed, human life must be secured. Accidents may occur either from carelessness or from faulty design. The former may be guarded against, but not absolutely prevented; for the latter there is no excuse. A system, to be absolutely safe, should include apparatus for preventing a drop, should all the ropes break at once, or if one should fail, for preventing abnormal speed due to excessive load or other cause; for holding the car stationary on the removal of power, or under any possible conditions of overload; for absolutely arresting the motion of the hoisting machine, and for removal of power when the car approaches the limits of travel; for immediate removal of power from the hoisting machine in emergency, if the cables slacken or in case of temporary cessation of supply; for receiving and stopping the car and the counterweight, should all the other devices fail to operate; for prevention of operation until hoistway doors are actually closed. The last condition is rarely fulfilled, the automatic house machine being alone in its compliance. Speed is of sufficient importance in the majority of cases to offset the results of possible carelessness on the part of the operator. In addition to the apparatus above mentioned, the cables for hoisting, the safety clutch for gripping the rails, the sheaves, bearing, and, in fact, all vital parts, should be of a strength far in excess of average actual requirements. This strength costs little and is of great importance. Easy, reliable control and economical operation are in a degree opposed, if the fixed charges are included in the latter. An ideally-controlled elevator would be capable of starting the car from rest with uniformly and rapidly accelerated velocity and minimum waste of power, of running the car at varying speeds, and of arresting motion, easily for ordinary stops, and immediately for emergencies. It would be noiseless, simple, and absolutely reliable in its action, and in case of accident or carelessness of operator, should automatically stop the car. It would be so designed and constructed as to preclude accident, no matter what the operator might attempt to do. These conditions are hard to realize completely in one system, but they have been partly fulfilled by several. Two general methods of con-

trol are recognized. The first allows of varying the speed from the car; the second does not, except for starting and stopping. The object of the first method is obtained in two ways—by a pilot motor operating to vary resistance in the main circuit, as in the Sprague system, with an inverse variation of the motor field strength; and the variable voltage, or Leonard, control, where each elevator motor has a separate generator, and the speed of the car changes in accordance with the varying electric pressure of the generator. This pressure is determined by a resistance in series with the small field current, and is adjusted from the car. Both methods meet most of the conditions imposed, and the question of choice for all speeds of less than 350 feet per minute is one of comparative economy. The Leonard system is employed only for worm-gear machines, and could not be operated with the present make of screw and multiple sheave machine. The variable voltage system allows of an ideal start and stop, whether from the standpoint of economy or from that of comfort; on the other hand, from the point of total economy in operation, the rheostat control is advisable because of the necessarily continuous operation, and the first cost of a separate generator for each machine. The proportion of time during which a car is in actual motion varies with the class of travel, but even in ordinary office-buildings it rarely exceeds five-eighths, and generally falls below one-half of the total operating period. In addition, each generator must be of capacity sufficient for the maximum starting load, and consequently runs at low efficiency. In this connection the following data from seventeen elevators, taken at random from more than a hundred tests, is of interest. The speed varied from 60 to 450 feet per minute, the maximum capacities from 1,500 pounds to 3,000; the maximum live load was 1,600 pounds, the mimimum 150 pounds, and the average only 593 pounds. A test on a tall office-building showed the average load to be less than one-seventh of the maximum, and the figures on another, where the elevators were apparently worked to their fullest capacity, showed it to be less than one-fifth. In general, the average live load varies from one-fifth to one-eighth of the maximum. As far as statistics show, the variable voltage system is less economical and simple than the ordinary rheostat control when applied to worm-gear machines; in smoothness of starting and operation it is superior. For low-speed machines, or for buildings where variable speed is not essential, a solenoid control answers all purposes, and its operation may be controlled directly by electricity from the car, or the shipper rope and wheel may be employed to close switches on the machine and operate the brake.

House elevators have an automatic control, which includes the following features: push button, or buttons, on each floor to bring the car to the landing; automatic locks, to prevent opening of the door except when the car is about level with the floor; door switches, stopping the car if door is opened; and a device pre-

venting the operation or calling of the elevator by more than one person at a time. This control works with complete safety and satisfaction with the various parts strongly and mechanically made. Small spring and trigger attachments are to be avoided, positive action, controlled electrically or mechanically, being substituted. Stopping the car is an important branch of the control, and is accomplished by removal of power, brake and short circuiting for heavy loads, and by the first and either of the other two for light loads. The difficulties are apparent; a car must be brought to rest within a few feet under widely-differing conditions of speed and load, and this involves as well the stoppage of the hoisting machine, the counterweight, and the sheaves. For this reason with heavy loads a device compelling the car to do work in stopping is almost a necessity for safe and easy operation. For very high speed machines still another device is used, which allows the brake band to touch the pulley just before stopping, causing the car to perform direct mechanical work, in addition to the electrical work caused by short circuiting.

The use of a brake depends largely on the construction of the worm gear. If this is of such nature as to allow a loaded car to reverse its motion, a brake is a necessity for holding the elevator in position. If the gear will reverse only when actuated by the motor, the brake becomes an emergency stop, and short circuiting, combined with the friction of the worm, is relied upon for ordinary occasions. This latter method involves the use of a worm gear with a more acute angle of contact, entailing increased friction and decreased efficiency, and requires a larger current for the down start and running. It has, however, an added element of safety.

Correct counterbalancing has an important bearing on the successful operation of the car. Efficiency and ease of running are in a degree opposed. Theoretically that system will be under the best control which has the least inertia; hence the use of a counterweight tends to reduce the certainty of control, and this result increases with the speed. Practice has shown, however, that, so long as the car exerts one-quarter to one-half more downward force than the counterweight, no trouble need be feared. With the drum machine and a speed of 350 feet a minute or less, two counterweights may be employed, the car counterweight exerting two-thirds as much force as the car unloaded, and the drum counterweight, the ropes of which wind on the drum in an opposite direction to the car ropes, exerting a force equal to that due to the unbalanced weight of the car and to the average load. Where lights or motors are to be supplied from the generators that supply the elevators, the question of economical operation gives precedence to steadiness of pressure, and it may prove advisable to have the counterweight balance one-half the maximum load. In high buildings a varying counterweight must also be employed to allow for the change in the force exerted by the ropes, as the

car moves up and down the shaft, and for the decrease in load in the upper portion of the building. This variable counterweight is a heavy chain, attached at one end to the bottom of the car, and at the other to the counterweight, or to an anchorage in the hoistway. With high-speed service the car should descend by its own weight, and should never be overbalanced. A system involving the opposite principle—i. e., a counterweight exerting a force greater than the car fully loaded—is in use, and should be condemned. The inertia of the system is nearly doubled, and, in case of accident and failure of safeties, the ropes are sure to break with the car at the top, dropping it the whole height of the building. With reduction of inertia in view, the counterweight for high-speed cars moves at only one-half or one-third the velocity of the car, the weight being increased in proportion. This reduces the total inertia of the system, and, in addition, decreases the cost of the counterweight guides and ropes.

The proper speed for a given building is one which will enable a trip up or down to be made in half a minute without stops. This figure will be modified to a certain extent by local conditions, but is a rough approximation. Apparently the speed should depend on the number of passengers to be carried, but this varying condition must be met by the size of the car, as there are certain periods of the day when the tenants all move, and high speed is of no advantage. Express elevators to the upper half or third of a tall building have been used with doubtful success. Crowding out of lower-floor tenants is almost prevented, but a number of annoying features have arisen, such as restriction of ease of inter-communication, mistakes in cars, etc. In addition, during all but the "rush" hours, two cars are fulfilling the duty of one. Velocity of service is increased by floor calls and indicators showing the position of the cars. Variable speed is a necessity where the cars are required to run at certain distances apart, or where elevators are run from a lighting plant.

For high buildings, with elevators running from 350 to 700 feet per minute, the increase in the inertia of the system and in the probable and possible strains due to sudden stoppage must be met by increased cable strength, fixed and absolute limits of travel, an underbalanced car with a counterweight moving at one-half or one-third its speed, etc. These conditions are filled only by the hydraulic and screw electric machines. The worm-gear drum machine is unfitted for such work, as it has an endless character of movement, and can not have double or triple ropes on the drum, on account of the size of drum necessary and the impossibility of equalizing their work at the machine.

THE TRANSMISSION OF POWER BY BELTS AND PULLEYS.

By C. L. Redfield.

(From Engineering Magazine, January, 1898.)

The tendency to seek after "some new thing," which is at least as old as literature and as strong in the department of mechanics as elsewhere, is perhaps in part responsible for the neglect into which the older methods of power transmission have recently shown a tendency to fall.

Electrical, or, in proper situations, pneumatic, transmission exhibits so striking convenience and so marked economy that there is a not unnatural disposition to concentrate attention upon these methods, and to slight correspondingly the older means of belts and pulleys.

But these older and more peculiarly mechanical contrivances are by no means superseded; they must be largely employed even in connection with the newer agencies, and in a vast number of establishments will continue to be the sole dependence. Part, at least, of the disfavor with which they are sometimes regarded arises from the very unfair method of judging a system by its abuses.

Comparison of the several rival systems is too often made in forgetfulness of the fact that, in delivering power through belts, pulleys and shafting, there are many elements to be taken into consideration. First, there is the diameter of the shaft, depending upon the power to be delivered and the revolutions per minute; second, the diameter and face of pulleys, depending upon the revolutions and belt speed required or assumed; third, size of belt, depending upon the force that must be delivered at the speed assumed. In ordinary cases these elements may be properly combined in an endless variety of ways, each of which would reach the required result, but with differing degrees of loss from friction. Any person who has had experience in a shop considers himself qualified to arrange pulleys and shafting so as to deliver any required power, but comparatively few know how to do so with a minimum of loss.

Before any rational effort can be made to reduce the losses in transmitting power through these elements, it is necessary to know where they occur and what causes them. They occur in the belts at the points where they bend around the pulleys, and in the journals of the shafts.

The first loss consists of the power required to bend and unbend the belts as they pass on and off the pulleys. While the loss at this point is relatively small as compared to that occurring at the other, it is not altogether insignificant, as will be seen by the fact that it is continually going on at four places on each belt in use. Furthermore, reduction of loss of this kind is worth considering, because it costs nothing, and is all gain, not being accompanied by any attendant loss. To transmit a given amount of power, a

certain number of cubic inches of belting must pass a given point in a given time. This may be accomplished by moving a large sectional area at a slow speed, or a small area at a high speed. In either case (or in any case) the product of the area multiplied by the velocity must not be less than a certain fixed quantity, the size of which depends upon the power to be transmitted. With the velocity fixed and the sectional area ascertained, we can obtain that area from either a thick and narrow belt or a thin and wide one. The force required to bend any body varies as the breadth, as the square of the thickness, and as the amount of the bend. For example, a belt two inches wide will offer twice as much resistance as another of the same thickness and only one inch wide, and a belt a quarter of an inch thick will offer four times the resistance of another only an eighth of an inch thick. Combining these two, we find that a one-inch belt a quarter of an inch thick is twice as stiff as a two-inch belt an eighth of an inch thick. As these two belts have the same sectional area and are consequently equal, it follows that less power (one-half) will be lost by running the thin belt instead of the thick one. As the loss depends upon the amount of the bend—that is, upon its sharpness—and as the sharpness of the bend depends upon the diameter of the pulleys, it follows that pulleys of large diameter are more economical than those of small diameter. It is seen, therefore, that, as far as the belts themselves are concerned, the maximum of economy is obtained by the use of thin belts on large pulleys.

There is still another advantage in the use of thin belts and pulleys of large diameter, which, while somewhat vague and incapable of valuation, is none the less real. A thin belt, by virtue of its pliability, hugs the face of the pulley more closely than a thick and stiff one, and consequently will not slip so easily under a given load. To prevent any belt from slipping, it must have a certain tension on the slack side, the subtraction of which from that on the tight side leaves a remainder that represents the force transmitted. The sum of these two tensions represents the pressure thrown upon the journals of each of the two shafts connected by a belt, and it is this pressure that forms one of the elements of the loss at those points. For each pound of tension added to the slack side of a belt to keep it from slipping another must be added to the tight side to overcome it, which two pounds, transmitted to the shafts, gives four pounds on the journals. It therefore follows that, for every pound removed from the slack side of a belt by reason of superior belt-adhesion, four pounds of pressure are removed from the friction surface at the journals. Pliability of belt and large pulley-diameter both tend to increase this adhesion, and thus to reduce the loss at points distant from themselves. For the same reason wooden pulleys are superior to iron ones, and leather-lagged pulleys, in turn, are superior to wooden ones.

The amount of power that can be delivered through a shaft varies as the cube of the diameter and as the revolutions per minute. Thus a two-inch shaft will transmit eight times as much power as a one-inch shaft at any given speed, and a given shaft will transmit twice as much power at 200 revolutions per minute as it will at 100.

The loss from friction varies as the weight, load, or pressure on the journals, multiplied by the speed. Considering the shaft by itself, its friction speed varies as the diameter, and its weight as the square of the diameter; consequently the loss from friction varies as the cube of the diameter. It is apparent, therefore, that, if the shaft carries no load but its own weight, it makes no difference what size is used, provided the speed corresponds to the size. In any shaft carrying a constant load other than its own weight, every change toward smaller diameter and greater number of revolutions increases the speed of the rubbing surface faster than the total weight on the journals diminishes, and there is consequently a loss; changing in the opposite direction will effect a saving. Usually the load varies when the speed varies, and in such cases the question of gain or loss depends upon whether the product of the load multiplied by the speed of the journal-friction is an increasing or a diminishing quantity.

A horse-power is 33,000 foot-pounds, which is a force in pounds multiplied by the number of feet through which that force must move in one minute to produce one horse-power. Thus, if the force is 100 pounds, it must move 330 feet per minute to make the product of the two equal to 33,000. Consequently, the faster a belt travels, the less pull it must exert to transmit a given amount of power. As several times this pull (whatever it may be) rests directly upon the journals of the shaft and becomes part of the load it carries, it is evident that high belt-speed is a potent factor in reducing loss by friction. The speed of belts may be increased either by increasing the revolutions of the shaft, or by enlarging the diameters of the pulleys, or by both. It may be stated as a general truth that every increase of belt-speed serves to lessen the loss of power through friction; but, as the amount of gain gradually diminishes as the speed increases, and as other elements enter into the calculation at very high speeds, there is a practical limit, lying somewhere between 4,000 and 7,000 feet per minute, beyond which further increase of belt-speed results in loss rather than gain.

Increase of belt-speed by increasing the revolutions of the shaft is not all gain, because the load carried by the shaft moves a greater distance on its friction surface. So also there is an attendant loss connected with increase of belt-speed by increasing the pulley-diameters, because, while larger diameters may have less face, the weight increases with the increasing diameter faster than it diminishes with the diminution of the face.

THE DE LAVAL STEAM TURBINE.

(*Engineering* [*London*], *November 26, 1897.*)

We have in a previous article on the Stockholm Exhibition referred to the De Laval steam turbine, and we now purpose giving a more complete and detailed account of this novel and comprehensive installation.

The principal feature of the De Laval steam turbine lies in the fact that the steam is blown into the buckets through a number of jet nozzles. These nozzles widen towards their outer end, thereby allowing the steam to expand down to the pressure in the exhaust chamber, whilst passing through the nozzles. By this arrangement the jet acquires a maximum of speed, the full available amount of statical energy being converted into dynamical. The steam passes through the buckets as a free jet, and has no tendency to leak out at the sides. The turbine wheel, in consequence, is able to run quite freely in its casing, the play allowed being, in fact, several millimetres.

The fact that the discharge of steam was with high pressures enormously increased when the orifice through which it flowed was divergent has, of course, long been known, having been discovered by experiment and accounted for by theory, so that the adoption of such a form by De Laval can hardly be considered a novelty. Further, it was also well known that could the purely mechanical difficulties of construction be overcome, a steam turbine should be extremely efficient. Thus, in 1885, Professor Unwin publicly stated that so soon as the difficulties arising from the excessive limit of speed required were surmounted, we should have "steam turbines smaller, cheaper, and not less efficient than ordinary steam engines." Whilst others have made extremely efficient steam turbines by adopting means for reducing these tremendous speeds to a more reasonable figure, De Laval has boldly accepted them, and is worthy of the greatest credit for the skill with which he has succeeded in justifying his audacity.

The expansion effected in the nozzle is perfect. The extensive experiments of Professor Zeuner prove that the steam thereby converts into kinetic energy identically the same amount of work as would be indicated in a cylinder, if the expansion were driven far enough to let the indicator diagram end in a point. In addition to this, the expansion is continuous, inasmuch as the steam at any one point of the nozzle is kept constant, so it will be easily understood, that any loss of steam through condensation in the turbine has been reduced to a minimum. The only surface where such condensation can arise is in the barrel of the nozzle, the one end being in contact with the cool, expanded steam. The total area of this surface in a turbine of 100 effective horse-power, however, only amounts to some ninety square inches. All the parts of the turbine, in contact with live steam, are well isolated.

Theoretically, the speed of the buckets should be nearly 50 per cent of the speed of the steam at the mouth of the nozzle in order

to attain the maximum efficiency. But for mechanical reasons a somewhat lower figure is adopted, although the speed of the De Laval turbine far surpasses that of earlier constructions. A 5 horse-power turbine, for instance, with a diameter of 4 in., runs at a speed of 30,000 revolutions per minute; a 50 horse-power turbine, 12 in. diameter, revolves at the rate of 16,000 revolutions per minute; whilst a 100 horse-power turbine, of 20 in. diameter, only revolves at the rate of 13,000 revolutions per minute. These high speeds are obtained without being accompanied by vibration, owing to the ingenious adoption of a flexible spindle, to which the turbine is attached. The speed is reduced by gearing down to a suitable degree for direct driving of dynamos, pumps and fans. By means of a counter-shaft the turbine will also do service as an ordinary motor for driving shafting, etc. The wheels of the gearing are cut with spiral teeth so as to combine the greatest possible strength with smooth running.

The speed is regulated by means of throttling, the steady, even revolution of the turbine, and the momentum of the running parts, making it an easy matter. The varying of the speed can be kept within 2 per cent, even if the full load is thrown off suddenly. It is, therefore, evident that the turbine is well adapted for the running of dynamos. Besides the turbo-generator, another practical application of the De Laval steam turbine is as a self-contained turbo-pump. These pumps are built as single or double, coupled in parallel or series, the latter giving very high pressure and efficiency. The speed of these pumps is somewhat higher than is the case with centrifugal pumps as generally offered, so that it has been possible to reduce the diameter of the pump wheel. This circumstance, coupled with the fact that belt-driving has been done away with, renders the efficiency of the pump itself very high. An efficiency of more than 70 per cent has been obtained with a pump of 5 horse-power, running at the rate of 3,000 revolutions per minute. Another adaptation of the De Laval turbine is for fan-driving, where equally satisfactory results have been obtained.

In the following table we give the consumption of steam per effective (brake) horse-power for different sizes and different pressures of steam, condensing and non-condensing.

The lowest consumption obtained so far was that at a test with a 300 horse-power turbo-generator, working at the Edison Electric Illuminating Company, New York. The steam pressure was 150 lb. per square inch, and there was no superheating; vacuum at outlet of turbine, 25.6 in.; steam consumption, 25.84 lb. per kilowatt-hour at full load.

It will appear from the above table that the difference in steam consumption when working condensing or non-condensing is unusually high. This is owing to the greater friction against the turbine wheel, when running in a medium of greater density. The increase of passive resistance, when working at high-pressure, thus fixes

Horse-Power.	Diameter of Turbine.		Initial Steam Pressure.											
			85.3 Lb. per Square Inch.			113.8 Lb. per Square Inch.			142.2 Lb. per Square Inch.			170.7 Lb. per Square Inch.		
	Non-Condensing.	Condensing.	Non-Condensing.	Vacuum.		Non-Condensing.	Vacuum.		Non-Condensing.	Vacuum.		Non-Condensing.	Vacuum.	
				25.2 In.	27.6 In.		25.2 In.	27.6 In.		25.2 In.	27.6 In.		25.2 In.	27.6 In.
	in.	in.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
5	4	4	50.0	35.9	32.2	46.3	34.8	31.7	43.7	33.7	31.3	41.7	33.1	30.9
20	8	9	46.1	25.6	22.5	42.3	24.5	21.8	39.9	23.8	21.2	38.4	23.1	20.7
50	12	12	40.8	22.7	20.1	37.5	21.6	19.2	35.3	20.9	18.5	33.5	20.3	18.3
100	16	20	28.4	20.9	19.4	35.3	20.1	18.3	33.1	21.6	17.4	31.5	18.7	17.2

Table gives steam consumption in pounds per brake horse-power hour.

the practical speed still lower than would be determined by the centrifugal force. In some cases a smaller wheel is used for high-pressure work, and a larger one for condensing. From this it will be understood that a turbine arranged to work either with or without condensing cannot attain to the greatest economy as regards consumption of steam in both cases, the turbine in this respect being in the same position as our ordinary steam engine. Running condensing the passive resistance of the turbine is only small—the actual friction in the bearings being all that need practically be taken into consideration—there being no stuffing-boxes, and the turbine wheel running without touching the casing. It is, therefore, claimed for the De Laval steam turbine, worked with a condenser, that it is an exceedingly economical engine at variable or reduced loads.

A test with a condensing turbo-generator of 33 units running under a steam pressure of 120 lb. showed a consumption of 33 lb. of steam per unit at full load; 33.2 lb. of steam per unit at four-fifths load; 37.3 lb. of steam per unit at half load; 43.5 lb. of steam per unit at quarter load.

The condenser work was included in these figures, the turbine itself driving its own air pump. The turbine was regulated by a centrifugal governor and the throttle valve acting on the inlet steam. The throttling was partly reduced by the shutting off by hand of a certain number of jet nozzles, the initial steam pressure before the nozzles being:

120 lb. at full load.
120 " four-fifths load (one nozzle shut off).
95 " half load (two nozzles shut off).
75 " one-fourth load (three nozzles shut off).

The simplicity of the construction of the De Laval turbine makes it not only cheap to manufacture. but also reduces the attention required to a minimum. These good qualities have brought about a considerable sale, over 1,100 steam turbines having from the end of 1892 to May, 1897, been sold from the Swedish Company and the "Societe de Laval" in Paris. The aggregate power of these turbines amounted to some 32,000 brake horse-power.

The exhibits at the Stockholm Exhibition were shown in different sections. In the Machinery Hall was exhibited a 100 horse-power turbine coupled to a continuous current dynamo of 66 units, two 100 horse-power turbines, coupled to alternators of 66 units capacity each, and one 50 horse-power turbine with a 33-unit alternator; one 10 horse-power turbo-generator acting as excitor to the above-mentioned alternators, while two turbo-pumps of 10 horse-power were shown in the same section. The pumps supplied the water to the jet condensers used at the large turbines.

In the brewery department, which was also located in the Machinery Hall, there was shown a 15 horse-power electromotor pump, and at the pumping station of the exhibition a 50 horse-power turbo-pump was at work, raising the necessary supply of water for various purposes in the exhibition. This pump could also, in case of emergency, be used as a stationary fire-engine, and steam was kept up continuously, night and day.

The separate pavilion of "Aktiebolaget de Lavals Augturbin" contained a very comprehensive and interesting exhibit of four turbo-generators of 66 units each, and two of 33 units each, connected with a high-pressure boiler. This plant was run during the greater portion of the day, yielding light and power to the whole of the exhibition. The steam pressure was kept at 1,700 lb. per square inch.

The general arrangement of the boilers is quite novel, as they are worked automatically. The coals are stoked continuously from a box above the boiler; this box is filled once every two or three hours, according to the load of the turbine. The stoking boxes in the pavilion in the exhibition were placed in the gallery. The grate is shaped like a ring, and has a revolving motion. The air necessary for the combustion is forced into the boiler by means of a fan coupled direct to the gearing shaft of the turbine. The steam pressure acts on the valves of the blast regulating the combustion, according to the quantity of steam consumed. The steam generator consists of several concentric spirals formed of solid-drawn tube, tested under hydraulic pressure of more than double that of the working steam pressure. The feed water is forced continuously into one end of the boiler and passes through the spirals one after the other with considerable velocity. The steam generated is submitted to superheating before passing to the turbine. There is no steam chamber or large recipient whatever in connection with the boiler; this would be impossible owing to the high pressure. The higher the steam pressure the smaller is the specific volume of the steam, and, consequently, the diameter of the tube can be kept small without involving any great loss in pressure from the velocity of the steam in the tubes. It is claimed that the danger of explosion is practically done away with in this system of boiler. In case a tube should actually burst, the steam in the broken part would immediately rush out, and as much steam would continue to do so as could pass through

an opening equal to two sections of the tube—one at each end of the fracture—until the boiler had emptied itself of its contents. The quantity of steam is not greater than what can pass through the flues of the boiler into the smoke-stack, without causing any damage whatever.

The exceedingly powerful circulation of the water in the boiler naturally makes the heating surface very effective; this circumstance, coupled with the fact that the spaces for steam and water are very small, has made it possible to bring the dimensions of this new boiler within a small compass. A combination, for instance, of a 100 horse-power turbo-generator, with boiler and condenser, occupies only a floor space of 18.9 ft. by 11 ft.

The exhaust steam from the turbine is condensed in a surface condenser; from this it is pumped into the hot-water receiver and then again fed into the boiler by the feed pump as in marine engines. By means of a special regulating apparatus the feed pump always feeds into the boiler as much water as the turbine consumes steam; by this arrangement the quantity of water and steam in the boiler, and at the same time the degree of superheat, are kept constant. At variable loads the fire and pressure of steam are regulated by the blast already referred to. The stoking is regulated automatically according to the rapidity of the combustion through the special construction of the revolving grate. The use of air blast has tended to considerably reduce the dimensions of the smokestack.

The De Laval boiler is self-contained, requiring no brickwork except the foundation. The air supply passes through an outer shell, whereby it absorbs the radiant heat.

At the Stockholm Exhibition, the boilers, as already mentioned, worked at a pressure of 1,700 lb., the temperature of the steam being about 600° Fahr. The working parts of the Laval turbine, it should be remembered, only come into contact with cool, expanded steam, by which arrangement very high degrees of superheat have been made practicable, which is synonymous with great economy of steam. After an extended practical experience as to the working of the boiler, we shall publish a complete report of the results as to the consumption of steam and coal.

THE GREAT RUSSIAN CANAL.

From Engineering [London], November 26, 1897.

Surveys are being made for the great trans-continental canal, which is to put the Baltic into communication with the Black sea. The surveys are now well advanced, and the spring will witness a commencement of the great—not to say colossal—enterprise. The canal is to be 216 ft. 8 in. wide at the ordinary water level, 116 ft. 8 in. at the bottom. Its depth will be 28 ft. 4 in. It will commence at Riga, and will follow the course of the Duna as far as Dunaburg. From that point it will be carried by a

costly piece of excavation to Lepel, on the Beresina. From the Lepel the course of the Beresina will be utilized until its junction with the Dneiper; and finally borrowing this latter stream, the canal will fall into the Black sea at Cherson. But of its whole length of 1,000 miles, the Baltic and Black sea canal will have accordingly only about 125 miles of artificial excavation; for the remaining 875 miles it will utilize the natural bed of one river, and two other rivers which will be canalized. Fifteen ports will be developed upon the route of the canal, besides two great terminal ports at Riga and Cherson; the enlargement of these two latter ports is being already actively proceeded with. Annexed is a list of the whole seventeen ports: Riga, Jakobstadt, Dunaburg, Lepel, Borissow, Robruisk, Kijew, Pergaslaw, Kunew, Cherkassy, Krementschug, Werchnedieprowsk, Jekaternoslaw, Alexandrowsk, Nikopol, Berislawi, Aleschki and Cherson. Each of these towns will become a seaport, and will be enabled to receive the largest ships along its quays, as the canal will have throughout a depth of 28 ft. 4 in., which will admit of the passage of the large sea-going steamers and ironclads. The canal is intended, indeed, to secure the passage of ironclads, as it has a double object—first, commercial, and secondly, strategic. The commercial importance of the canal will be considerably increased by branches which will be developed by deepening several rivers flowing into it; by this means such towns as Disma, Mozyr, Cernigow, Aster, Zitomir and Poltawa, which are all situated upon railway lines, will be attached to the new waterway. The Baltic and Black sea canal will be so substantially constructed that the largest steamers will be able to pass through it at a speed of six knots. At this rate the whole *trajet* will be made in 144 hours, as it is proposed that vessels shall be kept moving by night as well as by day by the aid of electric lighting. The total expenditure which will be involved by the construction of the canal, together with its equipment and branches, is not likely to be so large as might at first sight be supposed. The estimates foot up, at present, to 20,000,000*l*. The works will extend over five years, but the canal is expected to be brought into operation toward the close of 1902. The spring of that year will witness the completion of the Trans-Siberian railway, which is already in working order on its western sections as far as Kansk beyond Krasnoiarsk, while at its eastern end it is in operation from Vladivostock as far as the Amoor. Great works which are now in hand for the transformation of the port of Windau, securing its junction with the Niemen, will be completed about the same time.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—3d OF NOVEMBER, 1897.

A regular meeting (the 373d) of the Society was held in its rooms in the Monadnock block, Wednesday evening, 3d of November, 1897.

In the absence of the president and vice-presidents, the Secretary called the meeting to order. Mr. G. A. M. Liljencrantz moved that Mr. Isham Randolph be elected chairman. The motion was put, and carried unanimously.

The minutes were read and approved.

The Secretary reported for the Board of Direction the applications of Albert Reichmann and F. D. Anthony for membership.

Mr. Liljencrantz was called to the Chair and Mr. Randolph took occasion to state that no formal report had been prepared of the excursion of October 30, over the Englewood & Chicago Electric Street Ry., as the chairman and his co-laborers were not expert in that branch of engineering and wanted to get some data. He stated further that a lecture by himself on the Chicago Sanitary district work was in contemplation for November 30, to be fully illustrated, proceeds to be devoted to the library fund and other uses of the Society, it being thought that if the Society would interest itself in the lecture a considerable sum could be obtained.

Mr. Randolph resumed the Chair, and the next business in order was counting the ballots on the amendments to the by-laws. Mr. Liljencrantz, Mr. Keating and Mr. Chanute were appointed tellers. Completing their count, they reported that the amendments received 92 votes out of a total of 97. The Chair announced the amendment carried.

The Chair stated that Mr. Johnston, the president, was sick in bed, and his plans for the evening had not been received.

Mr. Liljencrantz made statement of the progress in co-operating with the Crerar library and in the purchase of books for our library.

The Chair called for suggestion of a topic for consideration. Mr. Bley offered "What lines should be laid down as a guide for engineering education?" This brought out a very considerable discussion from Messrs. Chanute, Liljencrantz, Randolph, Gasche, Beardsley, Bley, Windette and Rohrer.

Adjourned.

REGULAR MEETING—1st OF DECEMBER, 1897.

A regular meeting (the 374th) of the Society was held in its rooms in the Monadnock block, Wednesday evening, 1st of December, 1897, President Thos. T. Johnston in the chair.

The reading of the minutes of the previous meeting was omitted. The Secretary reported for the Board of Direction favorable action on the applications of Messrs. F. D. Anthony and Albert Reichmann, and the re-instatement of Noah Whitley.

The president called attention to the excellence of the lecture delivered by Mr. Isham Randolph, Tuesday evening, the 30th of November, at Central Music Hall, on the Chicago Drainage Canal.

There being no paper for the evening, a discussion was had on the inconvenient features of the Fahrenheit scale thermometer, and the possibility of changing the zero mark to freezing point.

The president called attention to a new manner of testing cement, named the "hot test," advocated by Dr. Preussing, a manufacturer of Hemoor cement, which consists in heating a briquette to 180° C, and then slowly cooling by adding water. He then gave an extended talk upon cements, which was followed by a discussion.

The meeting adjourned.

SPECIAL MEETING—22d OF DECEMBER, 1897.

A special (the 375th) meeting of the Society was held in its rooms on Wednesday evening, 22d of December, 1897.

President Thomas T. Johnston in the chair.

The minutes of the previous meeting were read and approved.

The Secretary reported for the Board of Direction the election on the 10th of December of Messrs. T. D. Anthony and Albert Reichmann as members and the receipt of application for admission as associate from J. W. Dickinson.

Mr. A. M. Feldman made a report of progress by the committee appointed to recommend books for purchase for the John Crerar Library.

The Secretary read the following letter:

Office of
DAVENPORT AND ROCK ISLAND CONSTRUCTION CO.
301 West Third Street.

DAVENPORT, IOWA, December 8, 1897.

To the Secretary of the Western Society of Engineers, Chicago, Ill.

DEAR SIR: I write to inform you of the death of Mr. E. G. Nourse, C. E., who I believe was a member of your society.

Mr. Nourse was my principal assistant, engaged in the construction of a bridge over the Mississippi river, between this city and Rock Island. He was killed this A. M. by the falling of a derrick. He had been connected with this work for the past two months. He has been residing lately at Moline, and leaves a wife and an aged father.

If you desire further information I would be pleased to give you as much as lies in my power, and should be glad to do so. Yours truly,

C. F. LOWETH.

Mr. Isham Randolph suggested that the Secretary acknowledge the receipt of the letter, ask the writer for all the particulars of Mr. Nourse's death. He then moved that the Chair appoint a committee to prepare a proper memorial of Mr. Nourse. Motion seconded and carried.

The Chair appointed the following gentlemen as members of that committe: F. G. Ewald, E. C. Shankland and Wm. Lee.

There being no other business, the Chair stated that he would undertake to relate some experiences he had during last spring in connection with the water works at Savannah, Ga., and proceeded with his relation of very interesting experiments and their results, delineating on the blackboard the situation in a clear manner. A brief discussion and explanation of particulars followed.

On motion the meeting adjourned. NELSON L. LITTEN, *Secretary.*

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid in completing valuable volumes for our files.

Since the last issue of the Journal, we have received the following as gifts from the donors named:

Barnard & Co., C., Paris, France.—Notes et Formules de L'Ingenieur, 11th Edition, 1898. Containing a vast deal of practical matter and in addition a technical vocabulary in French, English and German.

Strobel, C.L.,C.E.—Zeitschrift Architekten und Ingenieur,Vereins ZuHanover, Vols. XX to XXXVIII, inclusive, (except Vol. XXX) with Index. Also one Vol. of Indices, XVII to XXVII.

Hill, William R.,—7th Annual Report Syracuse (N. Y) Water Board.
8th " " " " " "

Chanute, Octave, C. E.—Areonautical Almanac, The, 1896.
Areonautical Almanac, The, 1897.
Proceedings of the International Conference on Aerial Navigation, held in Chicago, August 1 to 4, 1893.

Calkins, F. A.—Thirty Miscellaneous Pamphlets and Specifications.
Le Pont Sur La Mauche.
Report of State Engineer and Surveyor of Canals, New York, for 1863.
A System of Formulae for locating Railroads.
Explorations in Nevada and Arizona, 1874, War Department, U. S.
Transactions American Institute, New York City, 1859-60.
Port of Rotterdam, with a plan, 1893. De Jongh.
Official Report, Irrigation Congress, Salt Lake, Utah, 1891.

By Purchase.—Transactions Am. Society of Mechanical Engineers. Vols. I to IX, inclusive, and Vols. XVI and XVII.

By Exchange.—Transactions Am. Society of Mechanical Engineers. Vol. X.
Transactions American Institute Mining Engineers. Vols. I, II, III, IV and V.

U. S. Commissioner of Education.—Report of 1895-6. Vol. II.

U. S. Wind Eng. and Pump Co.—The Windmill as a Prime Mover. Wolff. Catalogue, 1898.

Smithsonian Institution.—Report of U. S. Natl. Museum, 1891.
Annual Report Board of Regents, 1895.

Benj. M. Wells, Supt. Streets.—Annual Report of Street Dept. of Boston, Mass. September, 1896.

F. A. Calkins—21st Annual Report Dept. Public Works Chicago, 1896.

W. S. Blatchley, State Geologist Indiana.—Annual Reports, 15th to 21st, 1885 to 1896, inclusive, 7 volumes.

Assn. Ontario Land Surveyors.—12th Annual Meeting. February, 1897.

Penn. State College.—1896-7 Calendar.

Indiana Engineering Society.—Proceedings of the 7th Annual Meeting. January, 1897.

S. S. Greeley.—Report of 7th Annual Meeting Assn. of Dominion Land Surveyors, 1890.
Selected Papers of Civil Engineers' Club, University of Illinois, 1890-1.
Proceedings 5th Annual Meeting Assn. Provincial Land Surveyors of Ontario, 1890.
4th Annual Report of the Factory Inspector of Illinois, 1896.
The Technic, Engineering Society Univ. Mich., 1896-7.
43d Annual Report R. R. Comrs. of Connecticut, 1895.

S. S. Greeley.—U. S. Geological Survey, Report on Coal and Lignite of Alaska, 1896.
University Minnesota.—Engineers' Year Book, 1897.
U. S. Navy Dept.—Annual Report of the Chief of the Bureau of Steam Engineering, 1897.
The Technical Publishing Co., London.—The Practical Engineer Pocket Book, 1898. A valuable pocket companion.
Mass. Institute of Technology.—Annual Catalogue, 1894–5.
E. Bernard & Co., Paris, France.—Cours de Mecanique Applique aux Machines. Par J. Boulvin.
University of Wisconsin.—A Comparative Test of Steam Injectors. By Geo. Henry Trautmann.
Institution of Civil Engineers, London—Vol. CXXX Minutes of the Proceedings, 1896–7. Part IV.
W. S. Love.—33 numbers Engineering News, 1897.
9 " Engineering Magazine, 1897.
5 " Engineering Record, 1897.
and 8 copies of miscellaneous publications.

The library and reading rooms are open from 9 A. M. to 5 P. M. on week days, except Saturday, until noon.

TO MEMBERS.

The Library Committee wishes suggestions as to good engineering books, new or old, that are desirable for our library. The aim is to give the greatest good to the greatest number of our members possible with the funds at our command, and the committee, composed of few members, cannot well judge wisely to meet the various needs of our membership.

Will each member please send to the Secretary of the Society the title of one or more books which he considers useful and authoritative in some line of engineering work? Please state title as fully as possible, together with the names of author and publisher, etc.

Any suggestions in regard to the library in general or in any detail will be gladly received.

PROGRAM OF PAPERS.

January to July, 1898.

February 2—Some Engineering Features of the Nicaragua Canal.

ALFRED NOBLE.

February 16—The South Works of the Illinois Steel Company.

VICTOR WINDETT.

March 2—The Evolution of the American Style of Water Wheel.

W. W. TYLER.

March 16—Mechanical Plants of Large Buildings.

DANKMAR ADLER.

Improved Portland Cement.

JOHN W. DICKINSON.

March 26—Ladies' Evening—Illustrated Lecture—Mexico.

WILLIAM J. KARNER.

April 6—Fire-Proof Construction.

WM. SOOY SMITH.

Fire-Proofing of Warehouses.

FRANK B. ABBOTT.

April 20—Topical Discussion Upon Electrical, Pneumatic, and Mechanical Power Transmission in Manufacturing Establishments.

PROF. D. C. JACKSON, H. M. BRINCKERHOFF, AND G. P. NICHOLS.

May 4—Locomotive Water Supply.

THEODORE W. SNOW.

The Cycloidal Pump.

CHARLES E. BILLIN.

May 18—Gauging of Streams.

WILLIAM G. PRICE.

June 1—Obstructive Bridges and Docks of the Chicago River.

G. A. M. LILJENCRANTZ.

Measuring Apparatus of Kings County Survey.

SAML. M'ELROY.

June 11—Ladies' Evening — Illustrated Lecture — Three Months Among the Engineering Works of England and France.

PROF. N. O. WHITNEY.

June 22—Railroad Draw Bridges.

WILLIAM H. FINLEY.

July 6—Establishment of Street Grades.

CHARLES P. CHASE.

In addition to the above, the following papers have been offered to the Society, the date of presentation to be announced later.

MASONRY—GEORGE S. MORISON.

TRACK ELEVATION OF C. & N. W. RY.—LOUIS H. EVANS.

INDEX.

VOL. 2.—JANUARY TO DECEMBER, 1897.

Western Society of Engineers,

ROOMS, 1736-9 MONADNOCK BLOCK,
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MEETINGS.

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Board of Direction: The Tuesday preceding the first and third Wednesday of each month.

INDEX TO ADVERTISEMENTS.

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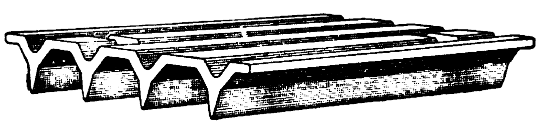
Wolhaupter Arch and Girder Tie Plate.

800,000 Sold In First 2 Months of 1897.



ARCH CONSTRUCTION, being most rigid form into which metal can be rolled. PLATE DOES NOT BUCKLE.

Unifies with tie and makes a perfect rail brace.
Compresses grain of wood and DOES NOT WORK LOOSE.
Contains least metal with greatest strength, therefore *The Cheapest.*

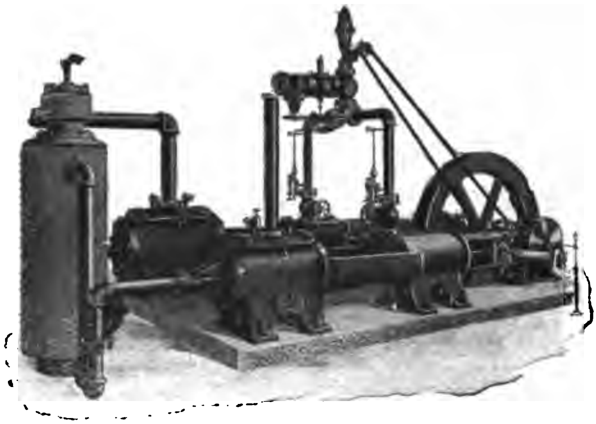
THE RAILROAD SUPPLY CO., CHICAGO.


DRAWING PAPER
TRADE MARK
KEUFFEL & ESSER CO.
NEW YORK.
BRANCHES: 111 MADISON ST., CHICAGO.
708 LOCUST ST., ST. LOUIS.
DRAWING MATERIALS
AND
SURVEYING INSTRUMENTS.

THE INGERSOLL-SERGEANT DRILL CO.

Havemeyer Building,
NEW YORK

Old Colony Building,
CHICAGO.



Duplex Air Compressor with Compound Air Cylinders and Receiver Intercooler.

This design gives 10 to 15 per cent increased efficiency over the common type of air cylinder, and is used by:

Gulf, Colorado & Sante Fe Ry.,	Galveston, Texas.
Atlantic & Pacific R. R.,	Albuquerque, N. M.
Southern California Ry.,	San Bernardino, Cal
Chicago, Indianapolis & Louisville Ry.,	Lafayette, Ind.
Detroit Bridge & Iron Works,	Detroit, Mich.

AND UNDER CONSTRUCTION FOR:

Pullman Palace Car Co.,	Pullman, Ill.
Chicago, St. Paul, Minneapolis & Omaha Ry.,	St. Paul, Minn.
Homestake Mining Co.,	Lead, S. D.
Jno. Mohr & Sons Boiler Works,	South Chicago.
Belleville Deep Well Water Co.,	Belleville, Ills.

The "New Ingersoll" Rock Drill.

1898 PATTERN NOW READY.

Among recent orders is one for eight drills from Mr. Thomas A. Edison, Edison, N. J.

RAND DRILL COMPANY

100 BROADWAY, NEW YORK CITY.
1328 MONADNOCK BLOCK, CHICAGO, ILL.

ROCK DRILLS AND AIR COMPRESSORS.

REVISED LIST OF MACHINES USED ON EACH SECTION OF THE DRAINAGE CANAL.

Section	A,	Shailer & Schniglau	6 Drills
"	B,	Heldmaier & Neu	1 "
"	D,	E. D. Smith & Co. (Rock taken out by Mason, Hoge, King & Co.)	6 "
"	1,	Griffiths & McDermott Construction Co	18 "
"	2,	McArthur Bros.; Winston & Co	10 "
"	3,	C. C. Gilman & Co	18 "
"	4,	McArthur Bros	11 "
"	4,	Sprague & Co	5 "
"	5,	Qualey Construction Co.	14 "
"	6,	Mason, Hoge, King & Co	15 "
"	6,	John Mitchell	4 "
"	7,	Gooch, Rinehart & Co	8 "
"	7,	Locher, Hanger & Mitchell	5 "
"	8,	Mason & King; Rosser, Hoge & Scruggs	22 "
"	8,	Winston & Co.	4 "
"	10,	E. D. Smith & Co	20 "
"	11,	Locher, Harder & Williamson	2 "
"	13,	Dandridge & Hanger; Wolfolk, Johnson & Comer	13 "
"	14,	Smith & Eastman	3 "
"	16,	Christie & Lowe	2 "
		Total	187 Drills.

AIR COMPRESSORS.

Section 1, One 16x24.
" 3, One 18x30, duplex.
" 6, One 20x30, duplex.
" 7, One 20x30, duplex.
" 10, Two 18x30, duplex.
" 11, One 18x30, duplex.
" 13, One 18x30, duplex.

Total	8 Air Compressors.
Drills	187
Total number of machines	195

Vol. II, No. 6. December, 1897.